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Umeda

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(54) **LIQUID EJECTING DEVICE**

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(51) **Int. Cl.**
B41J 2/175 (2006.01)

(52) **U.S. Cl.** **347/85**; 347/92; 347/93

(58) **Field of Classification Search** 347/84, 347/85, 86, 93, 92, 20
See application file for complete search history.

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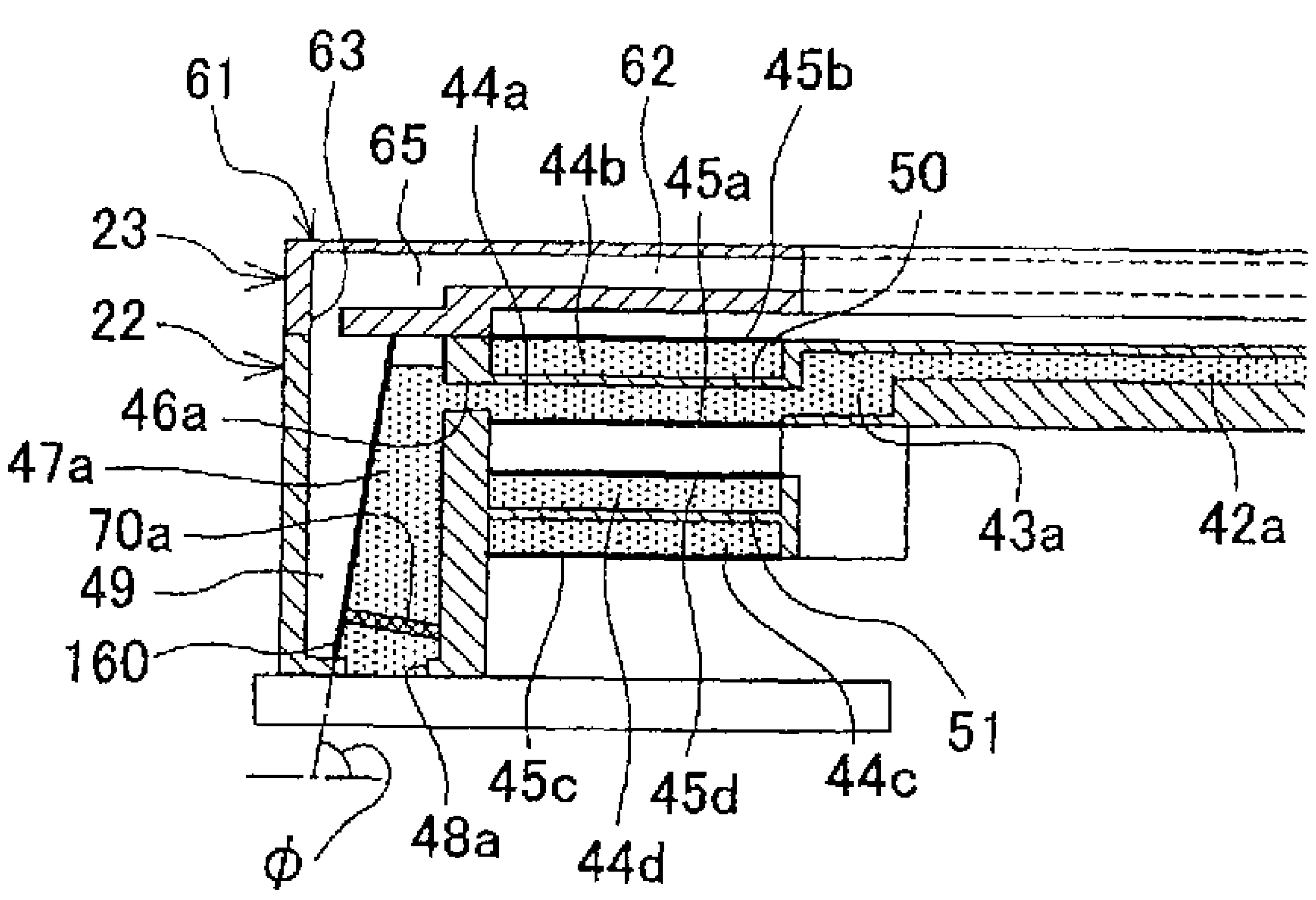
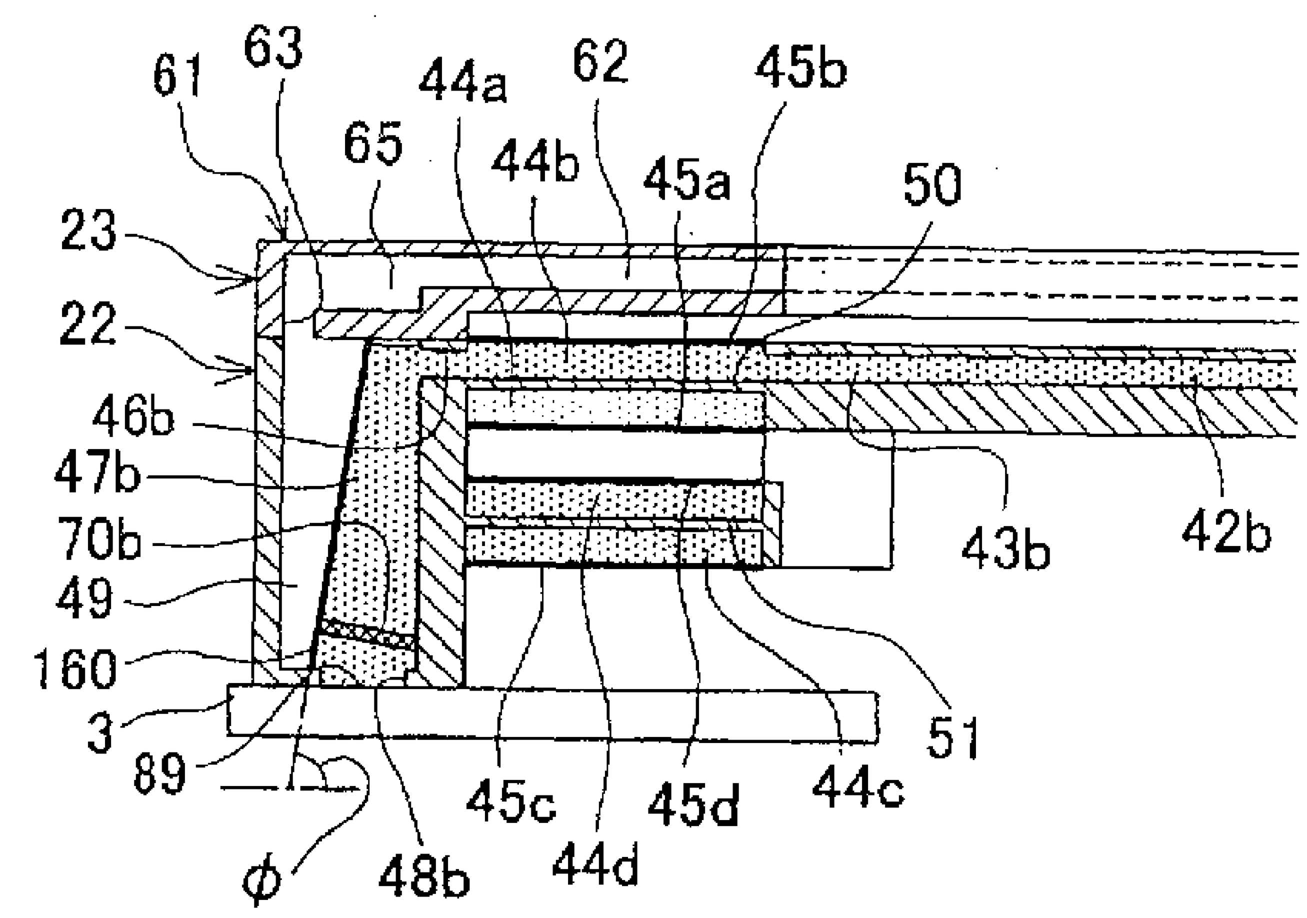
(74) *Attorney, Agent, or Firm* — Baker Botts L.L.P.

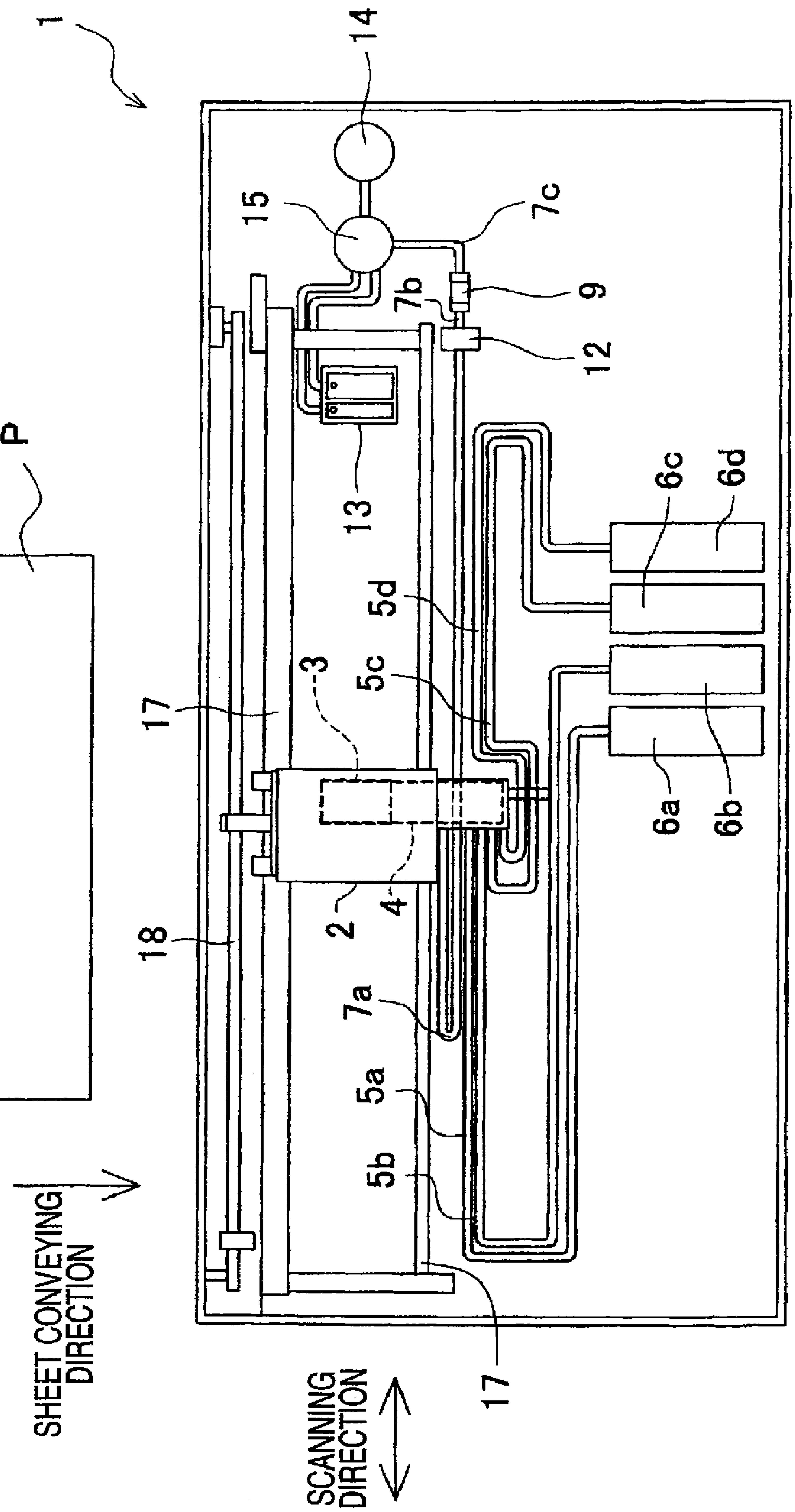
(57) **ABSTRACT**

A liquid ejecting device is provided. The liquid ejecting device includes: a liquid ejecting head including a nozzle for ejecting a liquid; a liquid supply channel for supplying the liquid to the liquid ejecting head; a discharge channel for discharging a gas in the liquid supply channel; a gas permeable film disposed in a connecting portion between the liquid supply channel and the discharge channel, the gas permeable film partitioning the liquid supply channel and the discharge channel; and a suction unit connected to the discharge channel so as to suction the gas in the discharge channel, wherein the liquid supply channel includes a first liquid flow channel extending in an extending direction intersecting a horizontal direction, and wherein the gas permeable film defines a part of the first liquid flow channel extending in the extending direction.

8 Claims, 12 Drawing Sheets



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7c
9
7b
12
13
P
6c
6d
5d
5c
3
17
6a
6b
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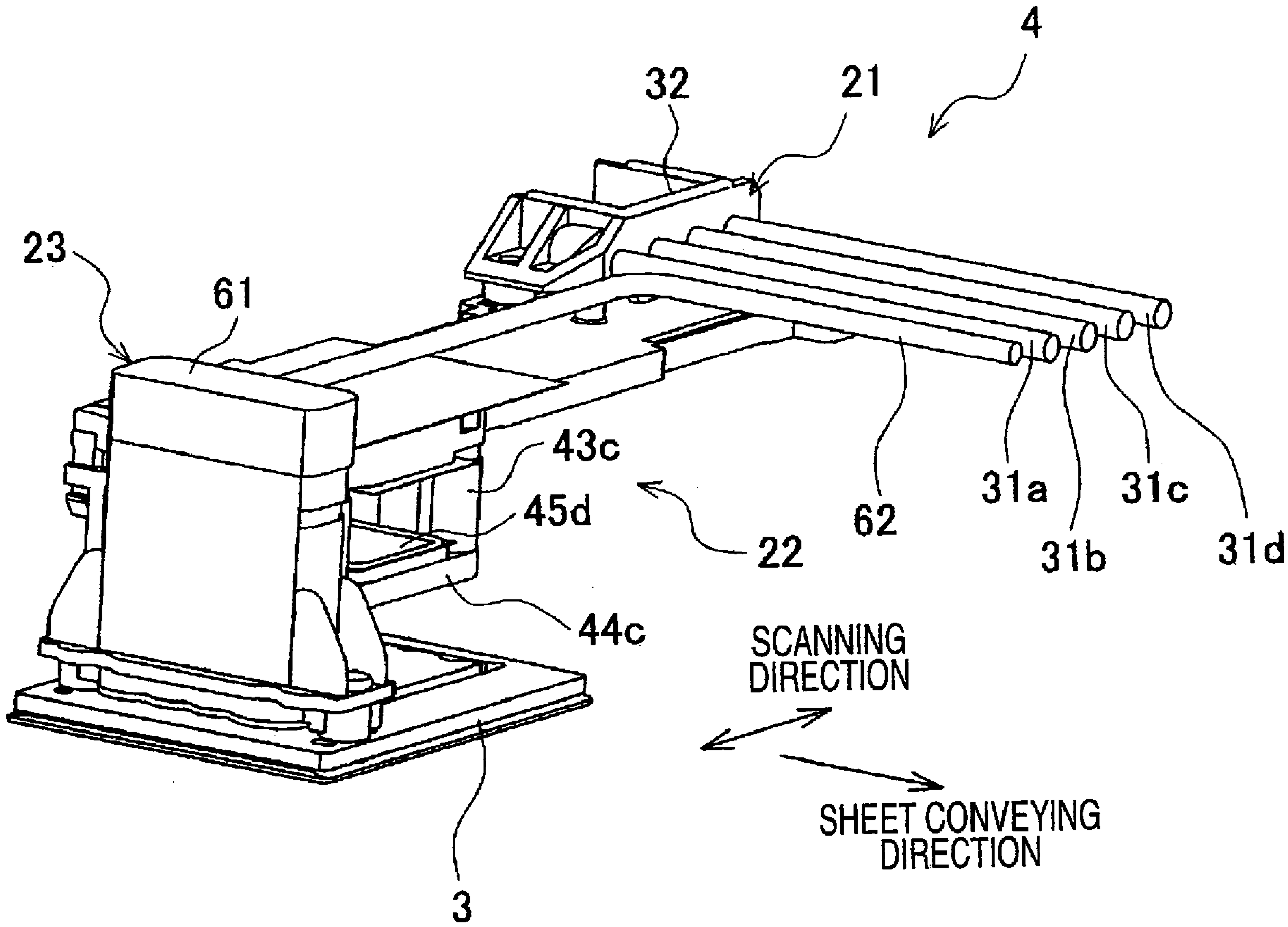
4
18
7a
5a
5b
17
SHEET CONVEYING DIRECTION
SCANNING DIRECTION

FIG. 1

FIG. 2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45d
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31a
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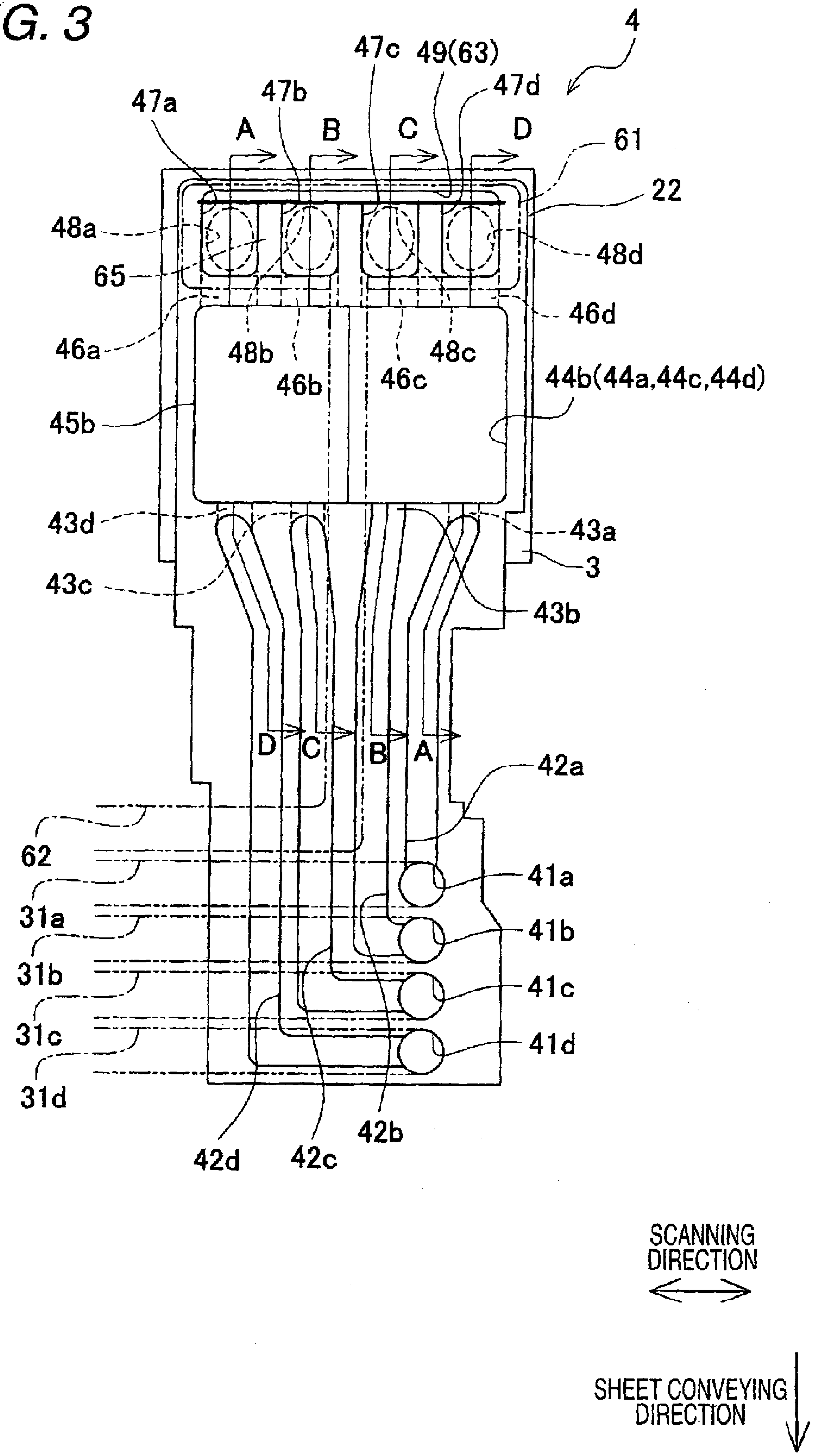
3

FIG. 3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48c
46b
46c
44b(44a,44c,44d)
45b
43d
43a
3
43c
43b
D
C
B
A
42a
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41d
31d
42d
42c
42b
SCANNING DIRECTION
SHEET CONVEYING DIRECTION

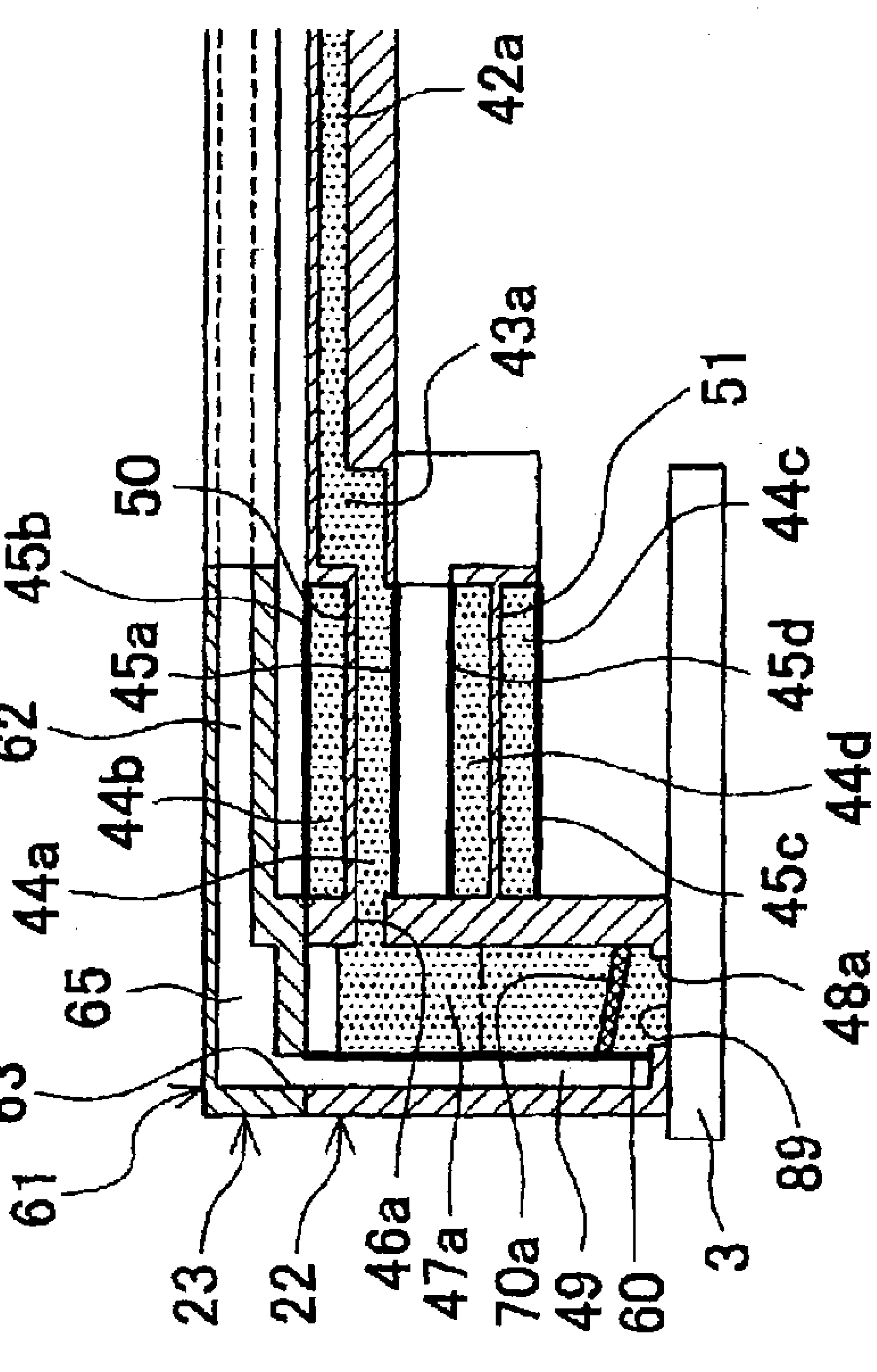


FIG. 4A

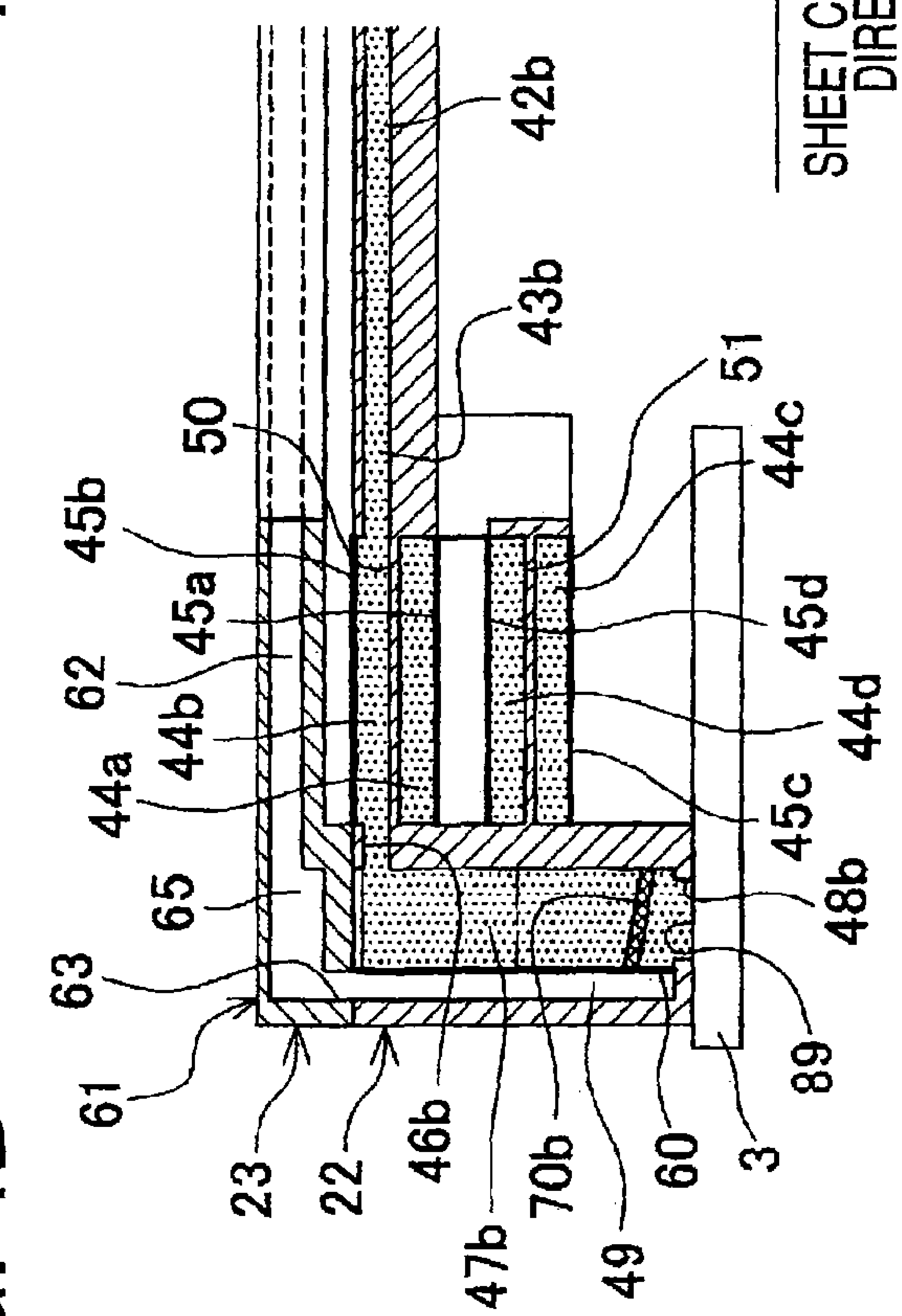


FIG. 4B

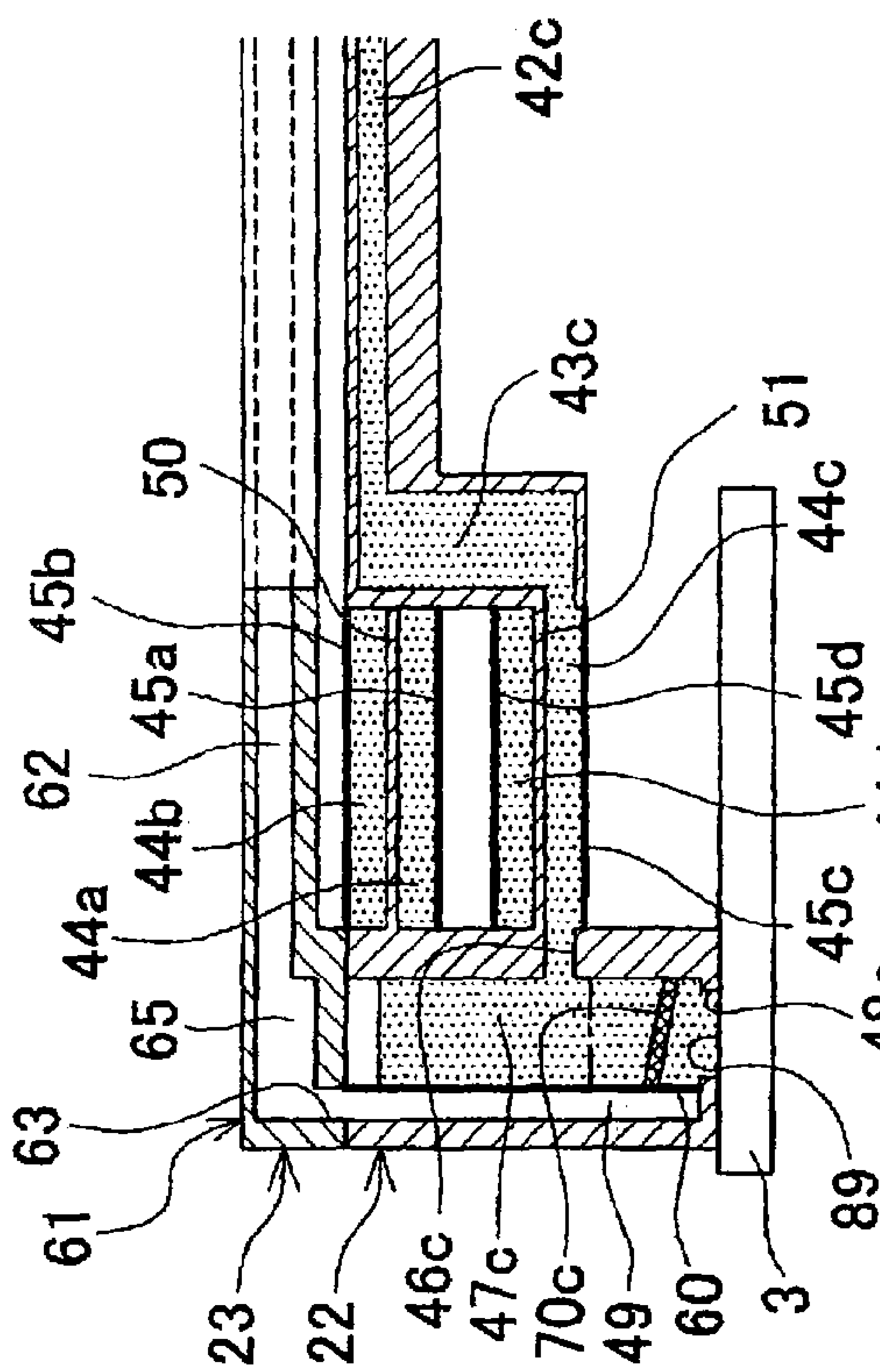


FIG. 4C

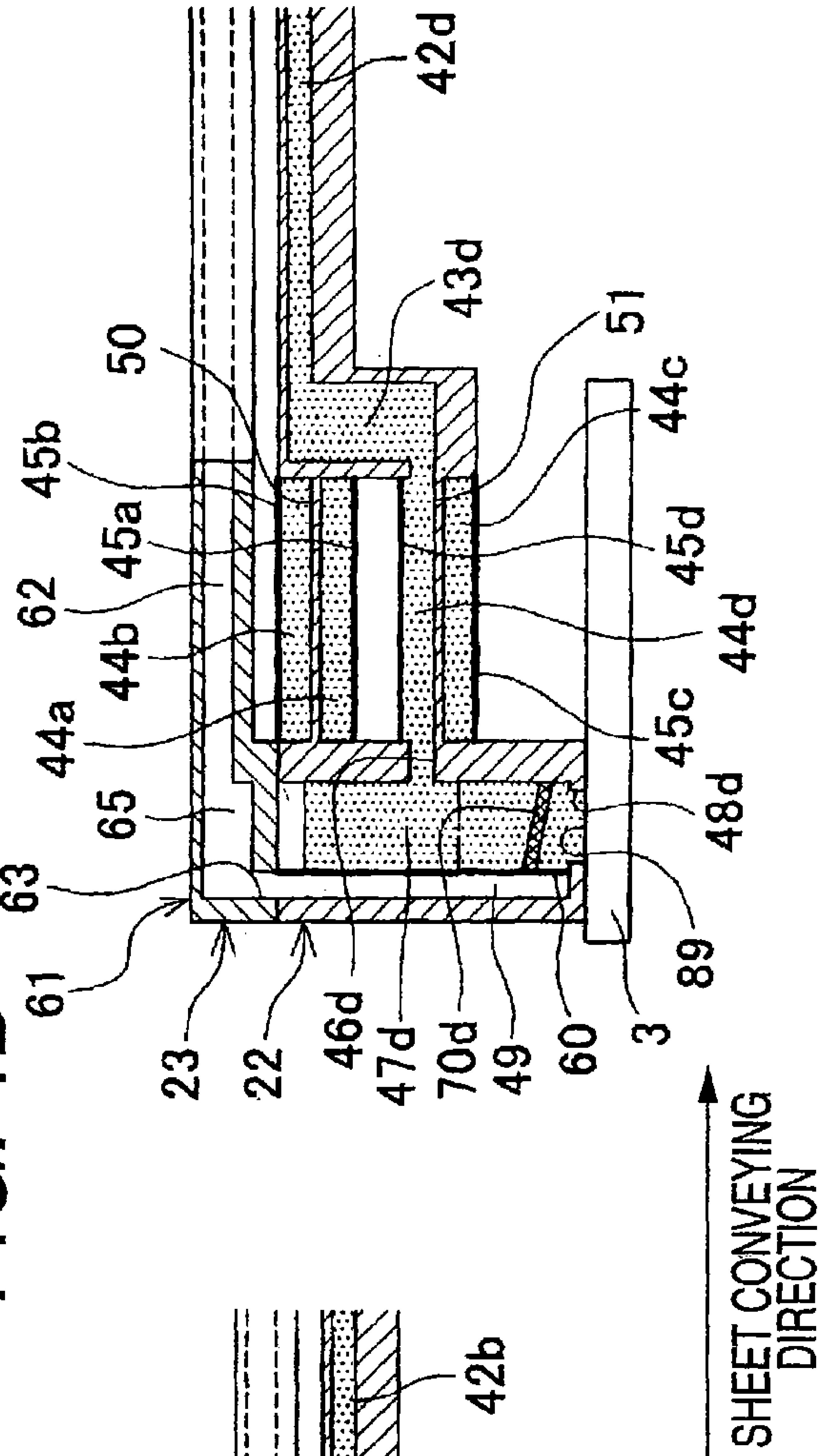
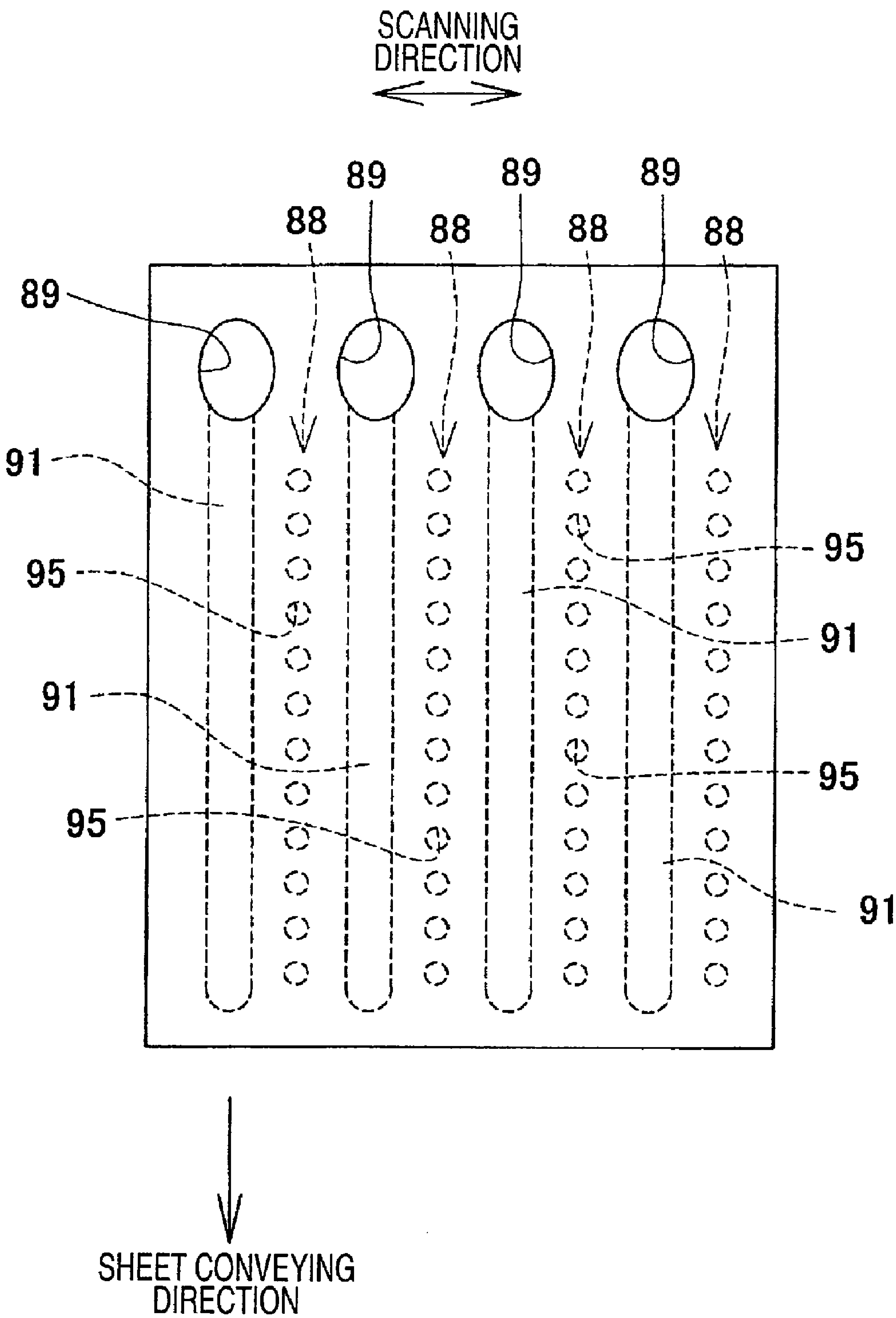


FIG. 4D

FIG. 5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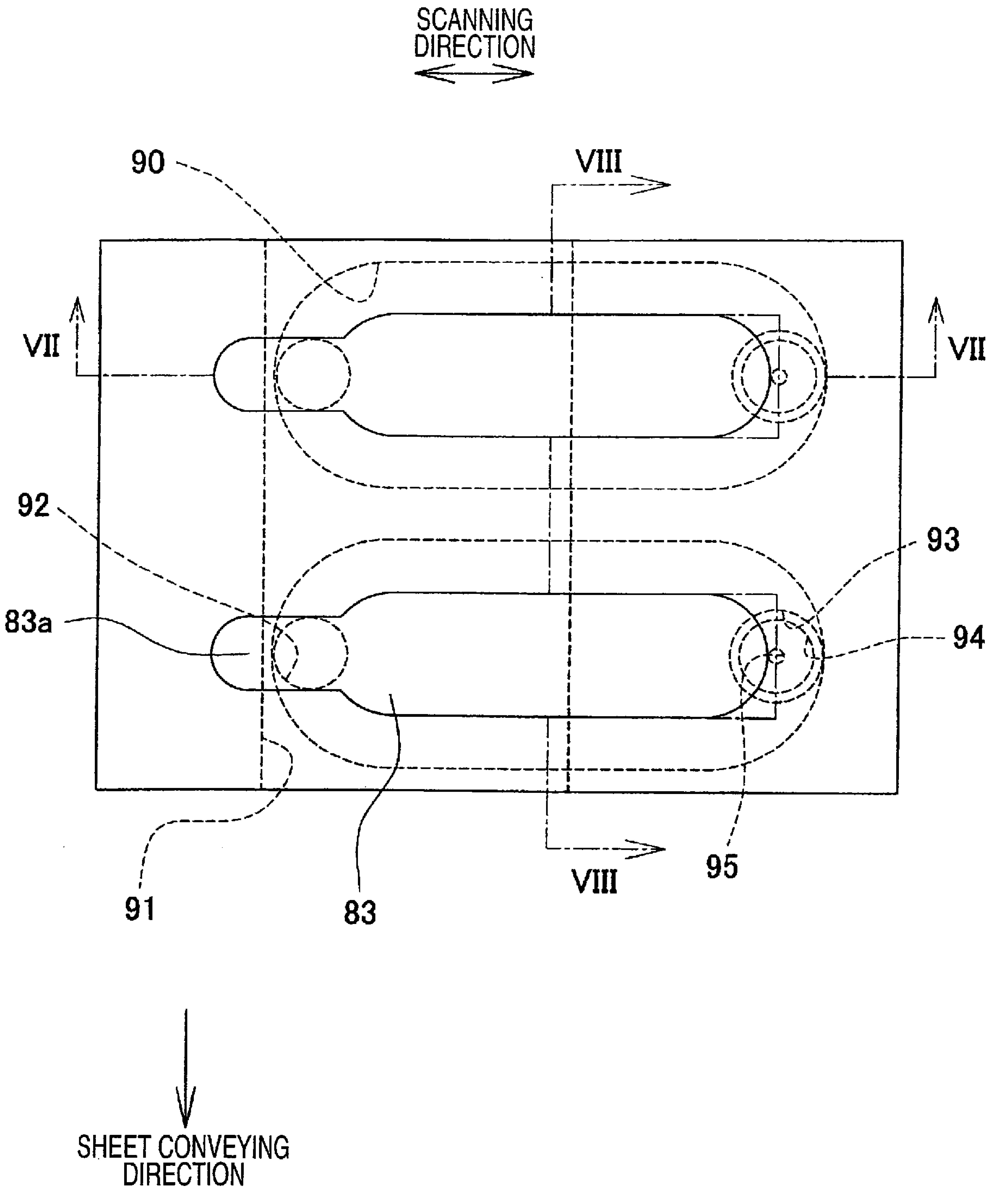
SHEET CONVEYING DIRECTION

FIG. 6


SCANNING
DIRECTION
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VIII
VII
VII
92
93
83a
94
95
VIII
91
83
SHEET CONVEYING
DIRECTION

FIG. 7

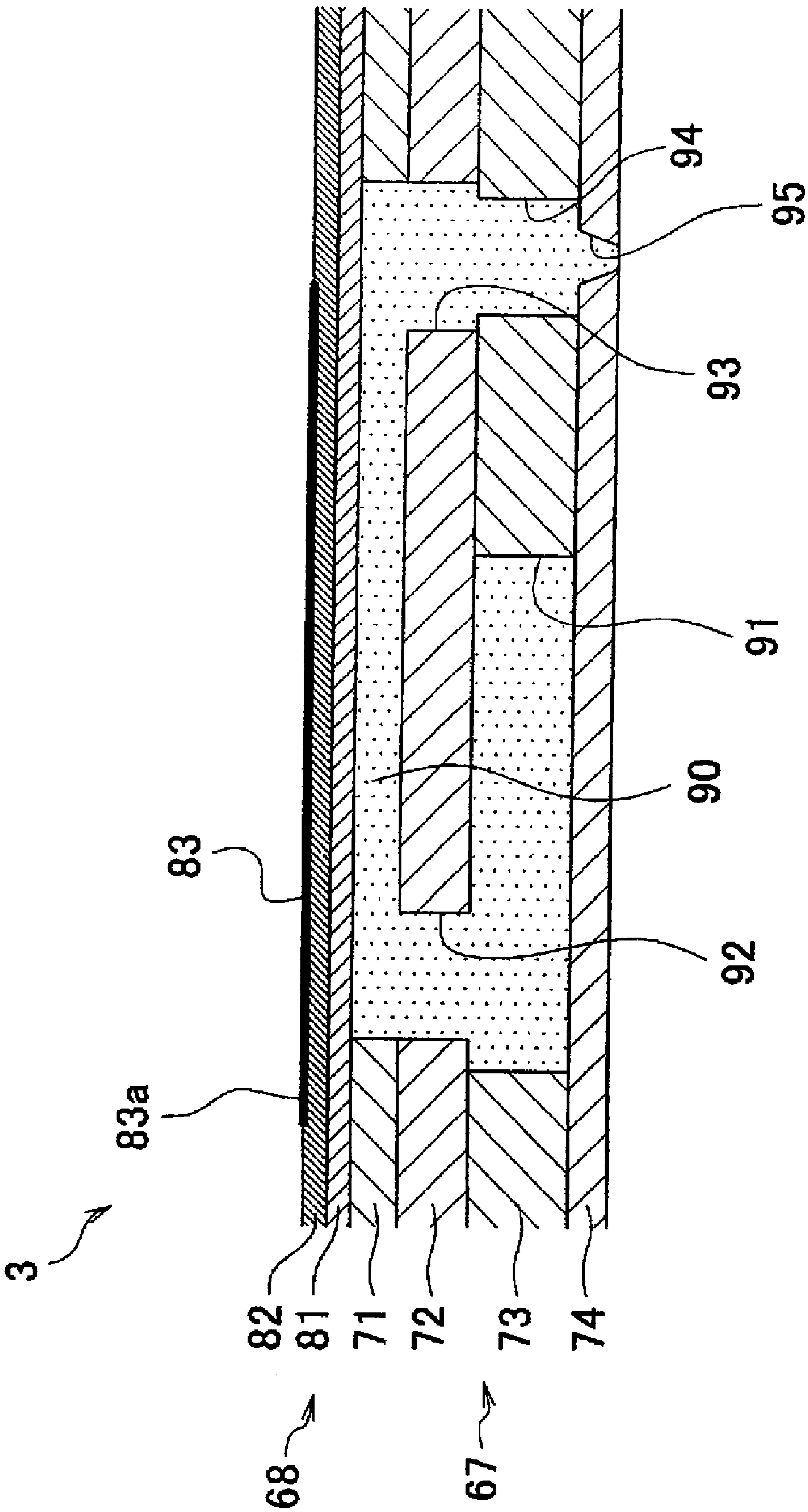


FIG. 8

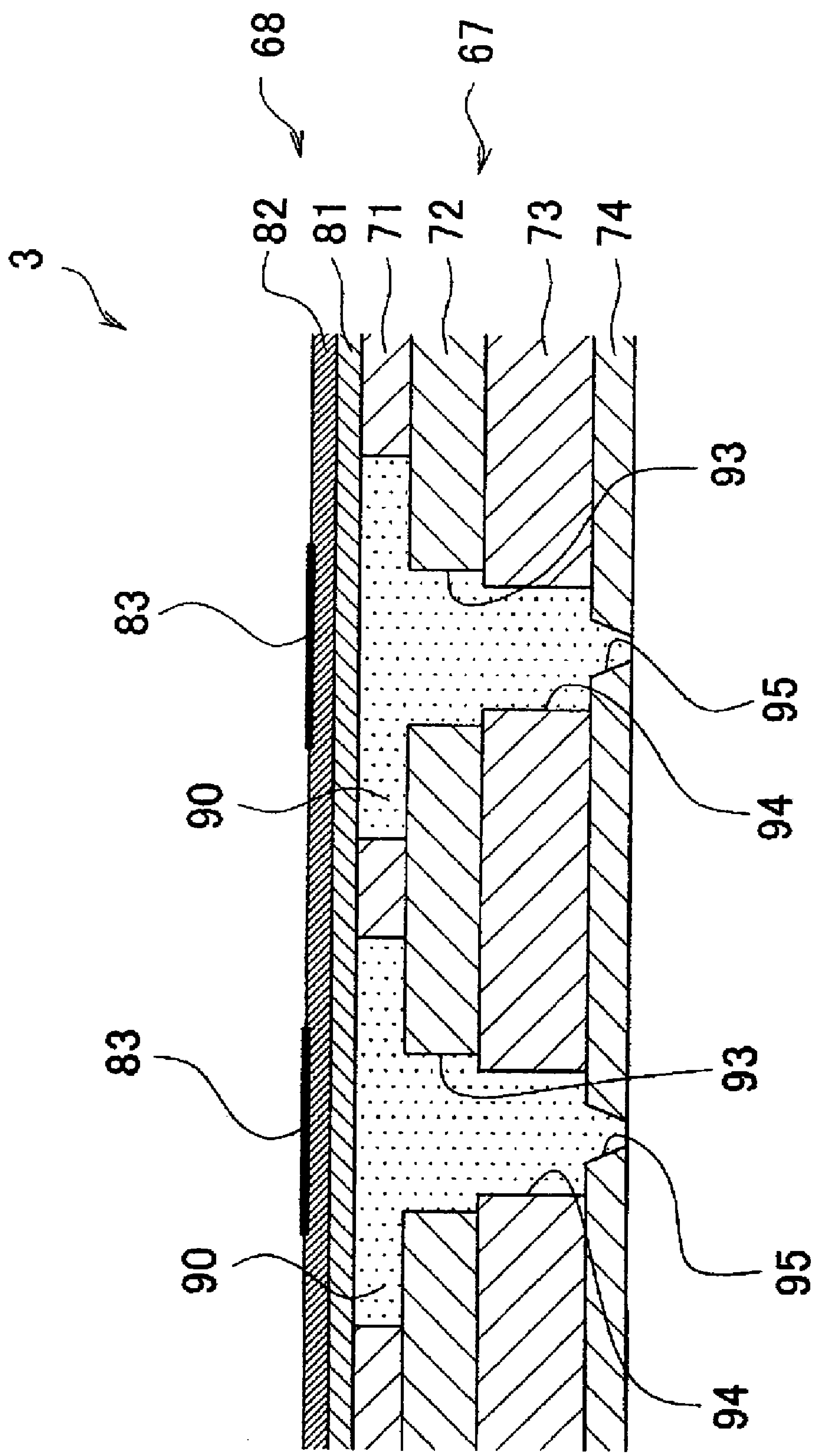


FIG. 9

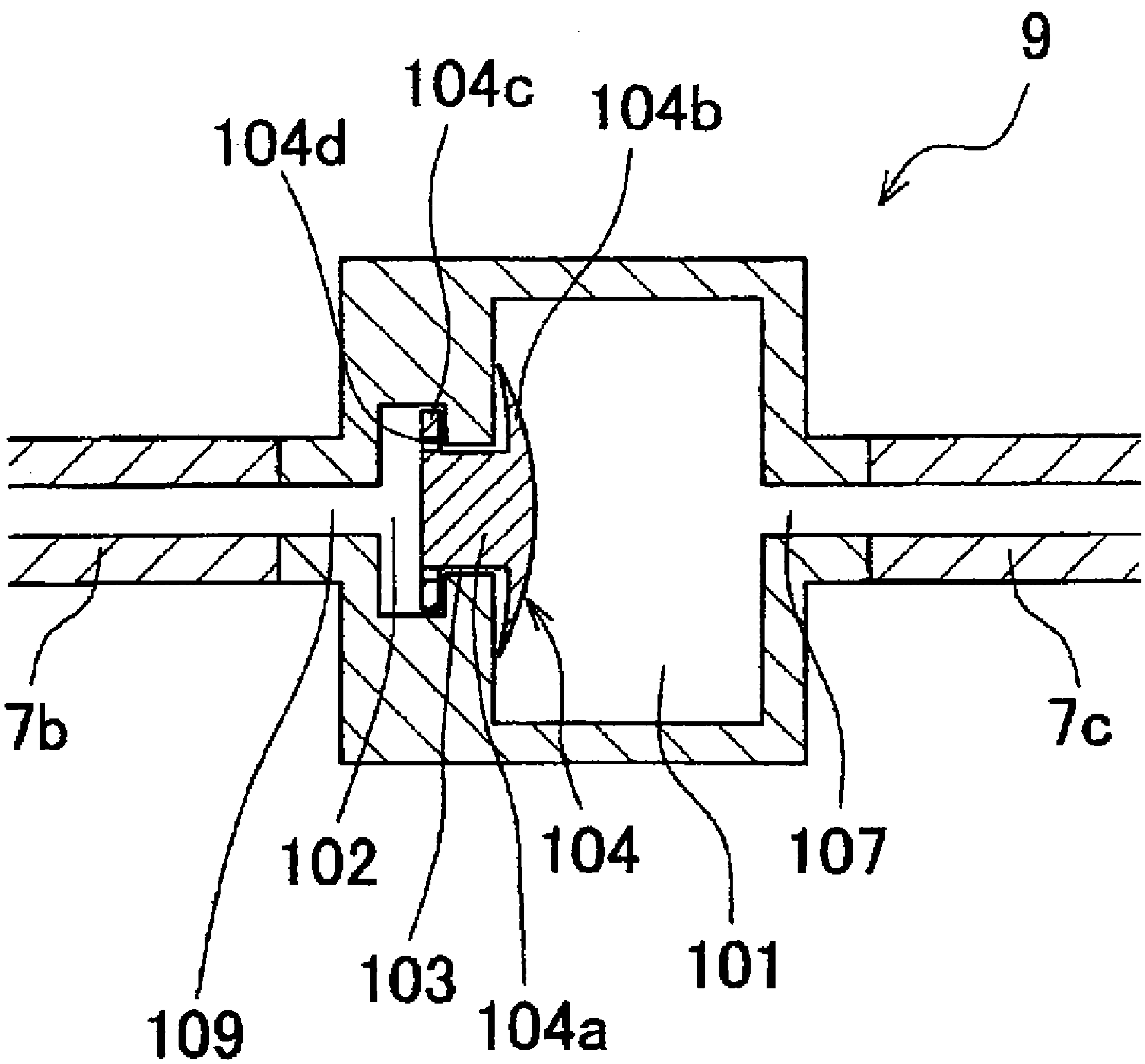


FIG. 10A

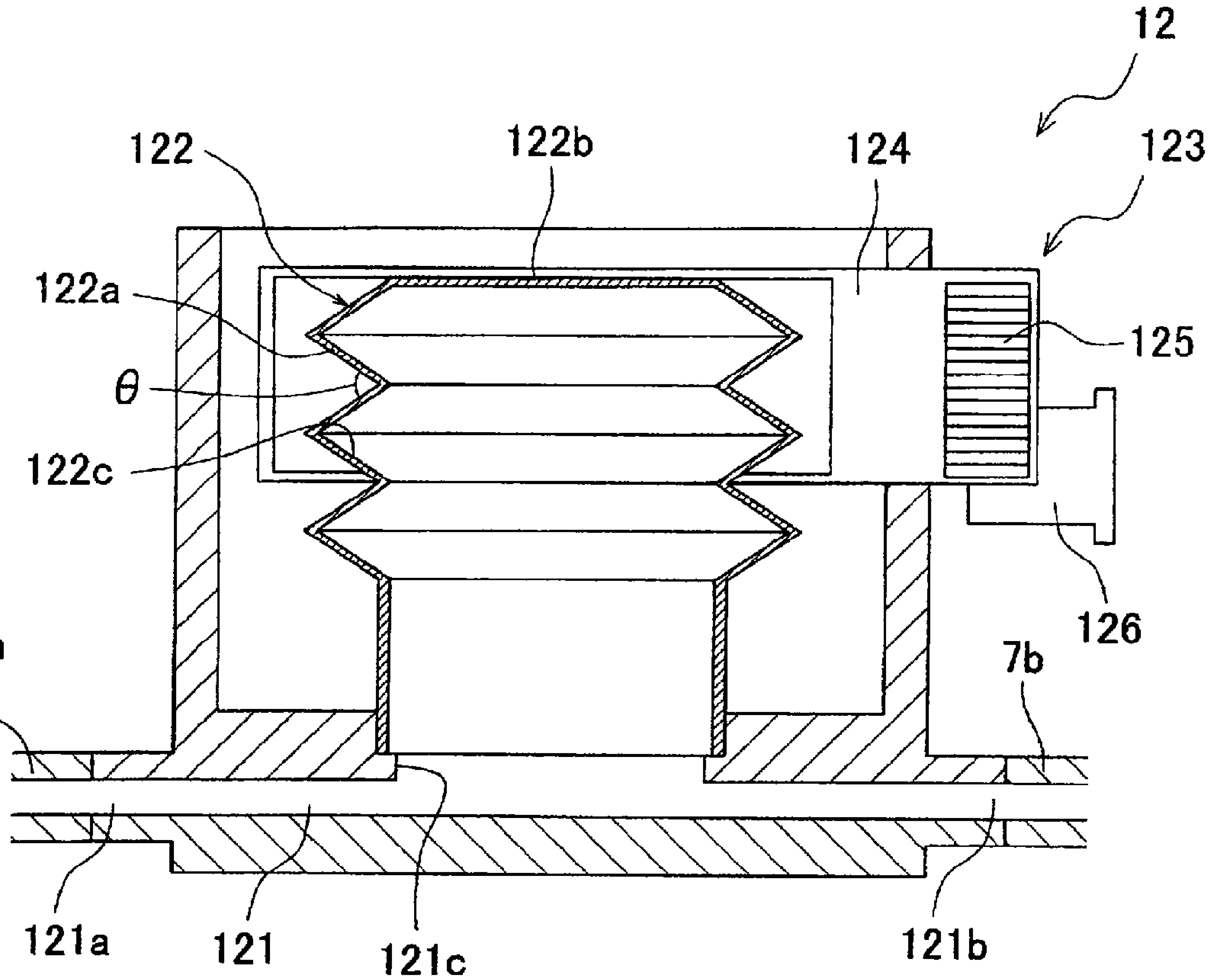


FIG. 10B

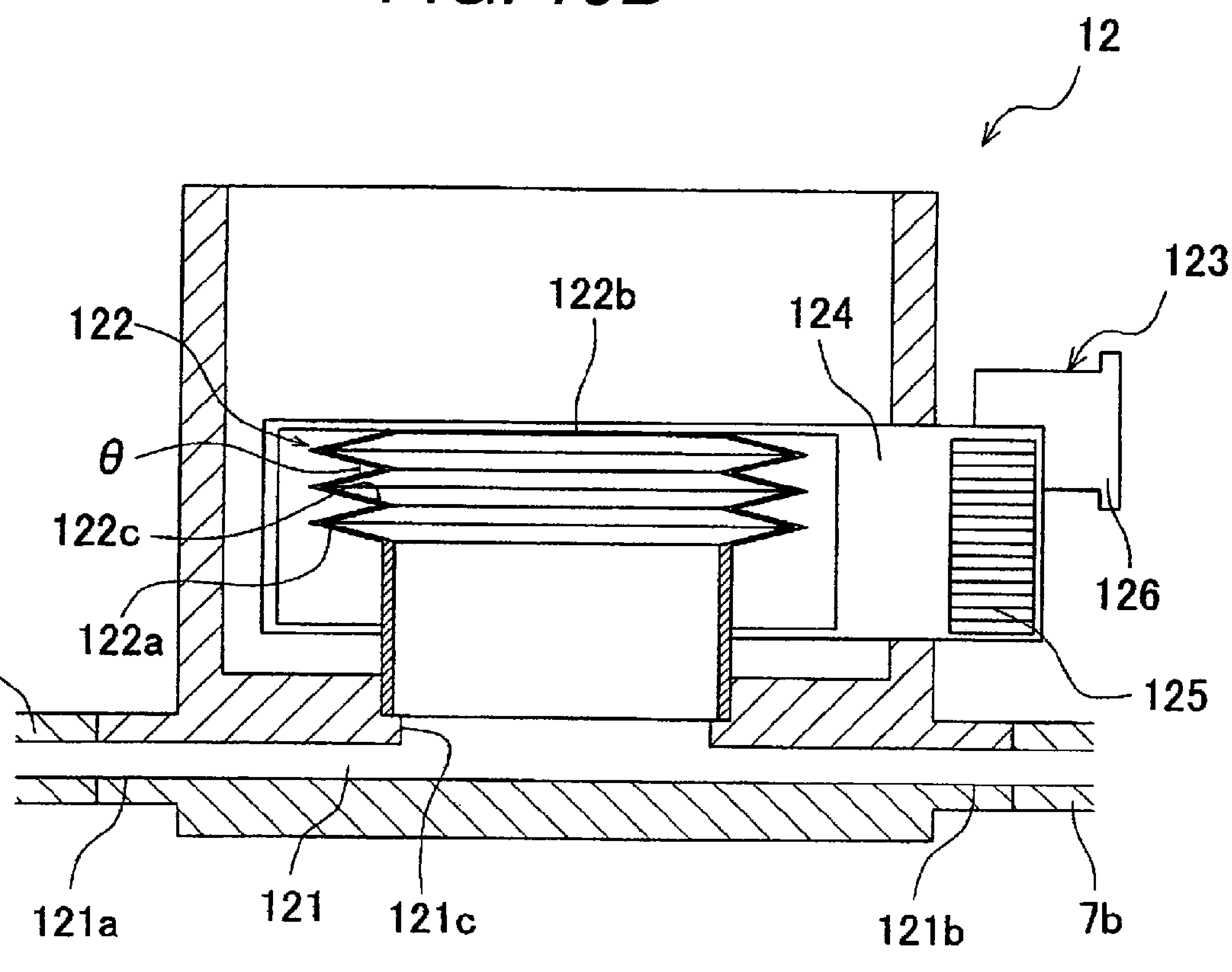


FIG. 11A

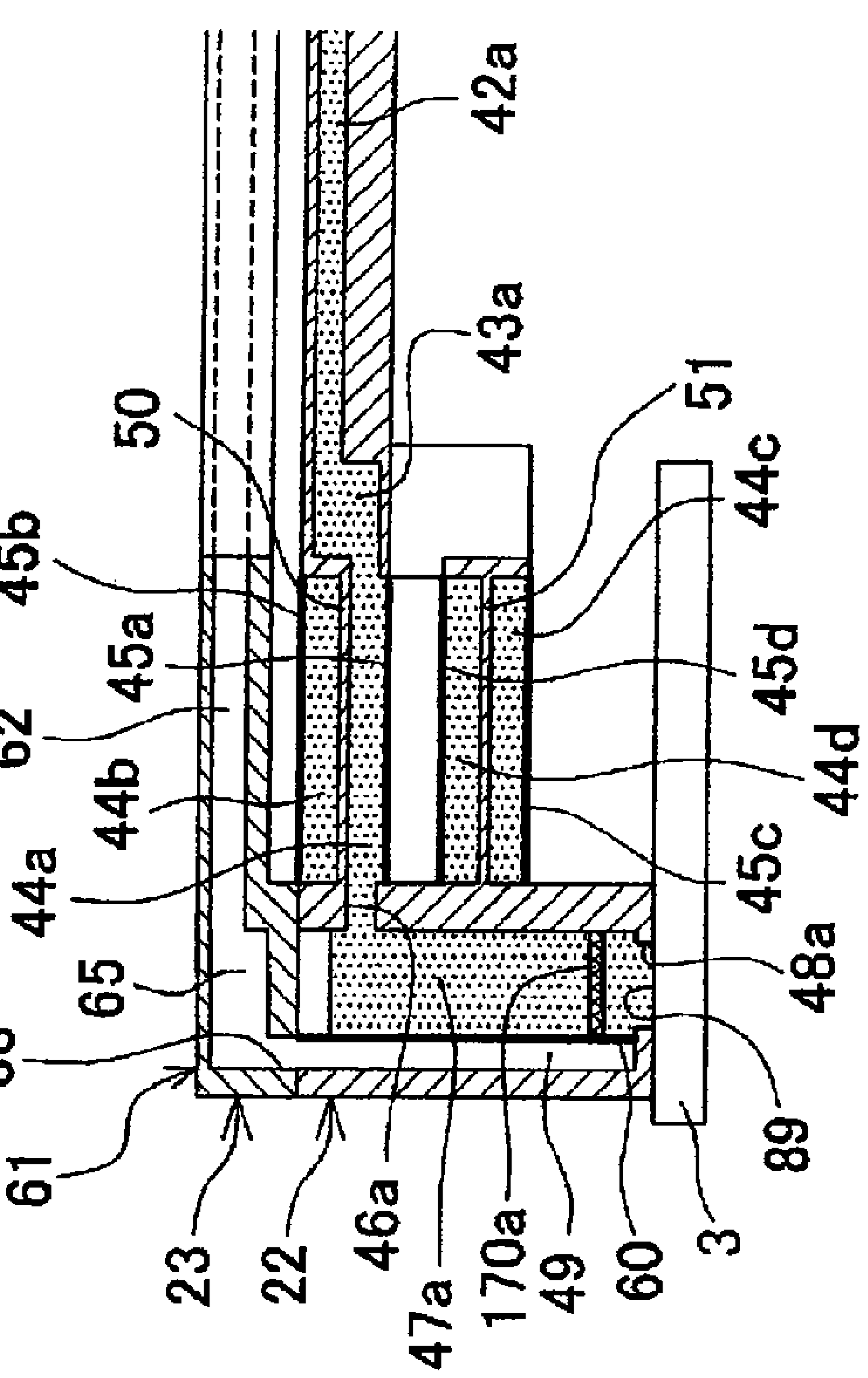


FIG. 11B

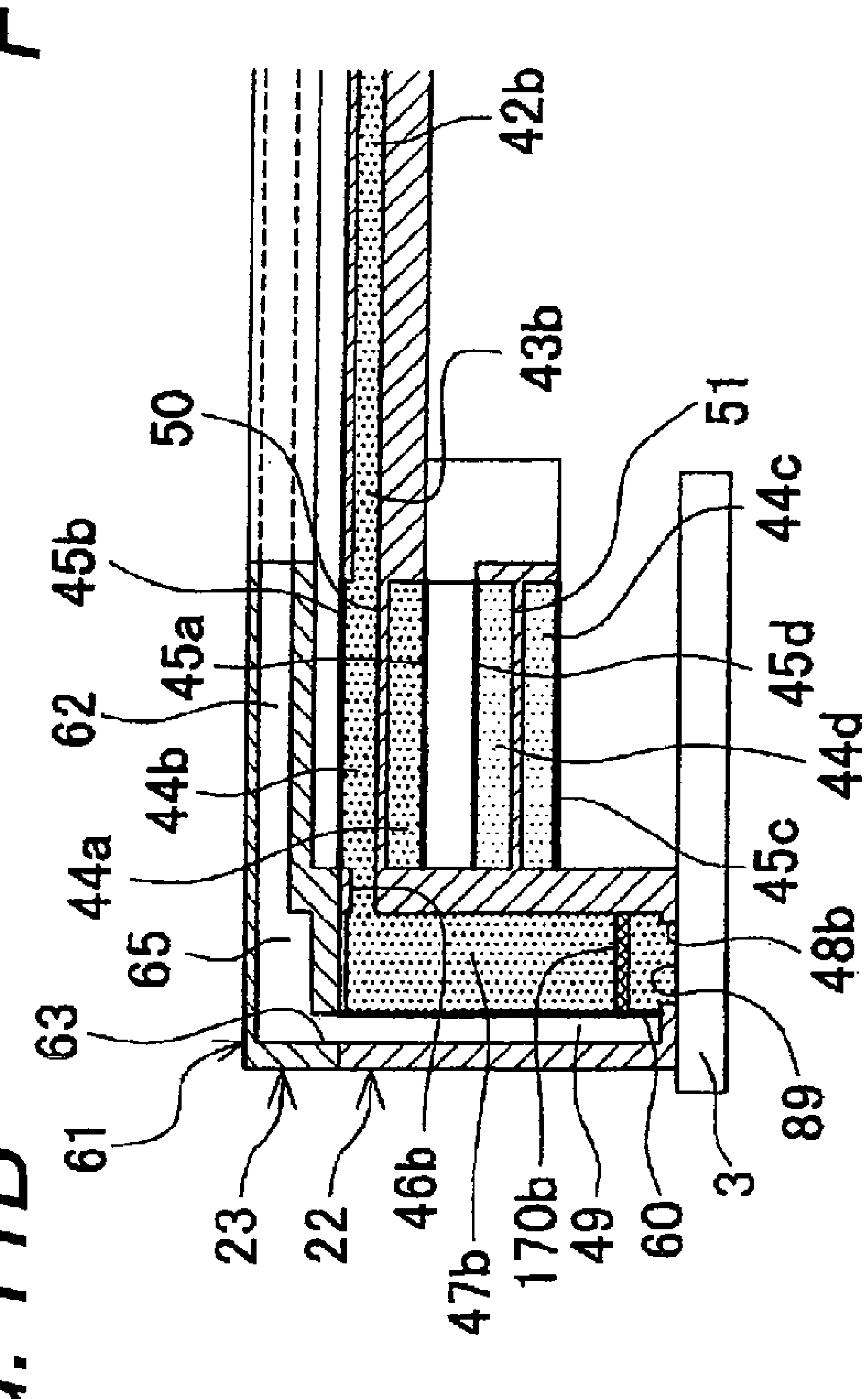


FIG. 11C

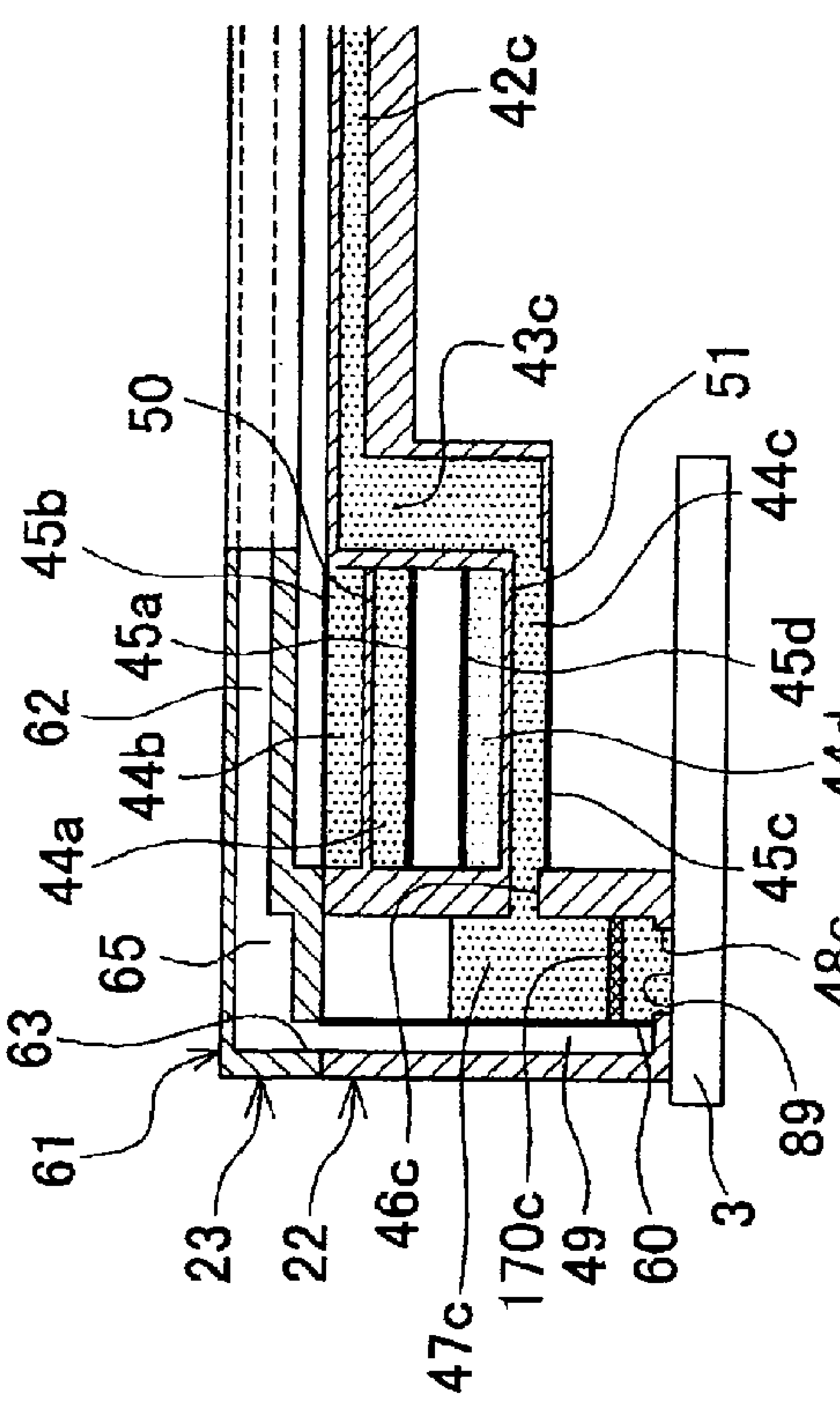
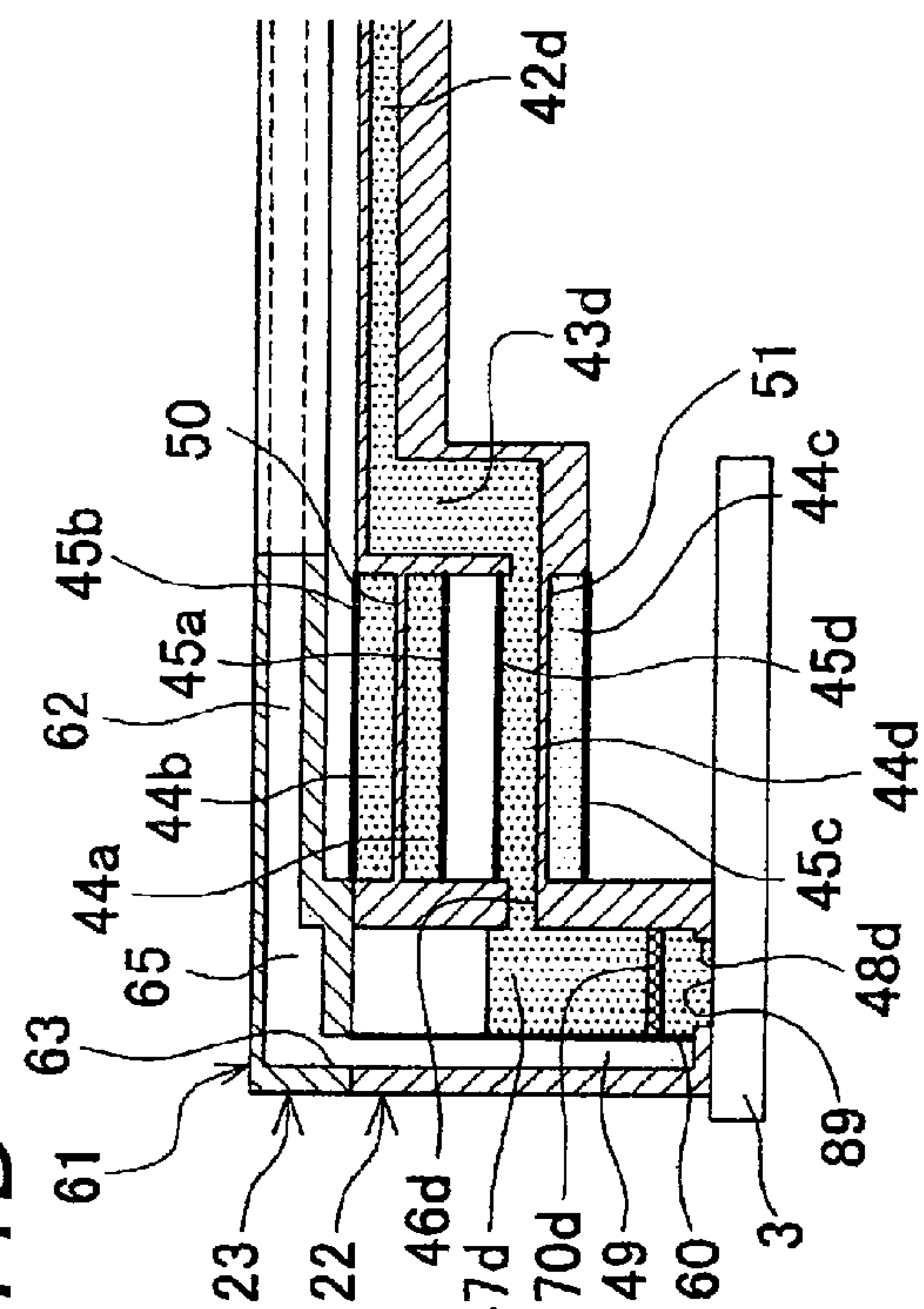


FIG. 11D



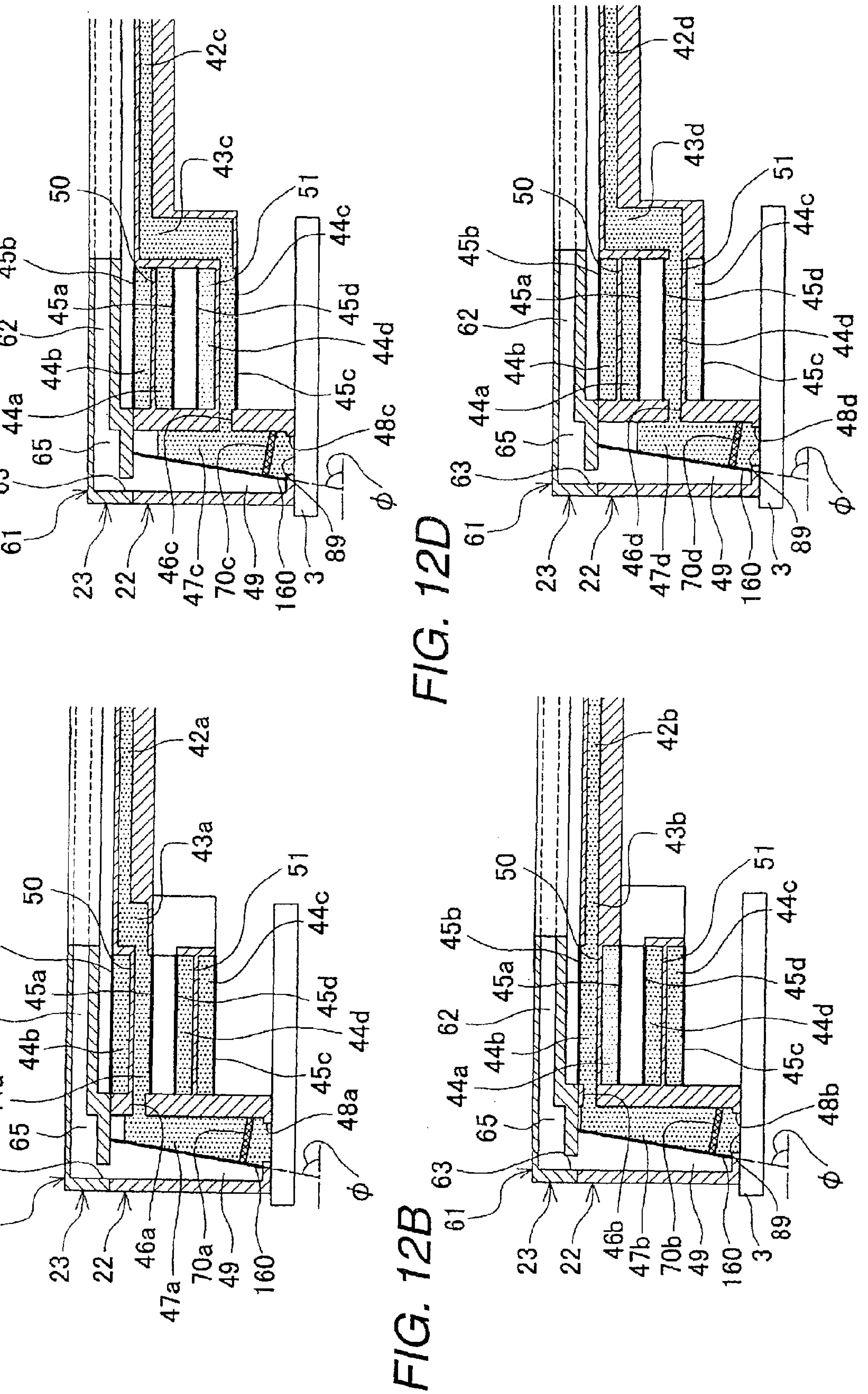


FIG. 12A

FIG. 12B

FIG. 12C

FIG. 12D

LIQUID EJECTING DEVICE

CROSS-REFERENCE TO RELATED APPLICATION

This application claims priority from Japanese Patent Application No. 2007-221040, filed on Aug. 28, 2007, the entire subject matter of which is incorporated herein by reference.

TECHNICAL FIELD

Aspects of the present invention relate to a liquid ejecting device ejecting a liquid from nozzles.

BACKGROUND

JP-A-2005-288770 describes an ink-jet printing device in which a sub-tank containing ink to be supplied to a print head is partitioned vertically by a ventilation film (gas permeable film), a part below the ventilation film serves as an ink chamber (liquid supply channel) containing ink, and a part above the ventilation film serves as an air chamber (discharge channel) to which air in the ink chamber is discharged. The air chamber is connected to a deaeration pump with a valve interposed therebetween, and the air in the air chamber and the ink chamber is discharged externally by actuating the deaeration pump with the valve opened to suction the air in the air chamber. By closing the valve after suctioning the air in the air chamber by actuating the deaeration pump, the air chamber is maintained in reduced pressure and then the air flowing in the ink chamber is discharged to the air chamber due to the reduced pressure of the air chamber. Accordingly, it is possible to prevent the air from flowing into the print head together with the ink at the time of supplying the ink from the ink chamber to the print head.

In JP-A-2005-288770, since air flowing in the ink chamber is lighter than the ink, the air is accumulated sequentially from the upper portion of the ink chamber, that is, the portion close to the ventilation film. Accordingly, in JP-A-2005-288770, when a large amount of gas flows in the ink chamber, the gas is accumulated at a position apart from the ventilation film and thus the gas accumulated at the position may not be efficiently discharged to the air chamber.

SUMMARY

Exemplary embodiments of the present invention address the above disadvantages and other disadvantages not described above. However, the present invention is not required to overcome the disadvantages described above, and thus, an exemplary embodiment of the present invention may not overcome any of the problems described above.

Accordingly, it is an aspect of the present invention to provide a liquid ejecting device which is able to efficiently discharge gas in a liquid supply channel even when a large amount of gas flows in the liquid supply channel supplying a liquid to a liquid ejecting head.

According to an exemplary embodiment of the present invention, there is provided a liquid ejecting device including: a liquid ejecting head including a nozzle for ejecting a liquid; a liquid supply channel connected to the liquid ejecting head to supply the liquid to the liquid ejecting head; a discharge channel connected to the liquid supply channel through a connecting portion to discharge a gas in the liquid supply channel; a gas permeable film disposed in the connecting portion between the liquid supply channel and the discharge channel, the gas permeable film configured to pass the gas and do not pass the liquid, the gas permeable film partitioning the liquid supply channel and the discharge channel; and a suction unit connected to the discharge channel so as to suction the gas in the discharge channel, wherein the liquid supply channel includes a first liquid flow channel extending in an extending direction intersecting a horizontal direction, and wherein the gas permeable film defines a part of the first liquid flow channel extending in the extending direction.

According to another exemplary embodiment of the present invention, there is provided a liquid ejecting device including: a liquid ejecting head including a nozzle surface, the nozzle surface including a nozzle for ejecting a liquid; a liquid supply channel connected to the liquid ejecting head to supply the liquid to the liquid ejecting head; a discharge channel connectable to a suction pump which suctions a gas in the liquid supply channel through the discharge channel; and a gas permeable film which passes the gas and does not pass the liquid, and which is disposed between the liquid supply channel and the discharge channel and defines a part of the liquid containing unit and a part of the discharge channel, wherein the liquid supply channel extends in a direction intersecting the nozzle surface, and wherein the gas permeable film is provided such that as an amount of the liquid in the liquid supply channel reduces, a contacting area between the gas permeable film and the liquid in the liquid supply channel reduces.

BRIEF DESCRIPTION OF THE DRAWINGS

The above and other aspects of the present invention will become more apparent and more readily appreciated from the following description of exemplary embodiments of the present invention taken in conjunction with the attached drawings, in which:

FIG. **1** is a diagram schematically illustrating a configuration of a printer according to an exemplary embodiment of the invention;

FIG. **2** is a perspective view schematically illustrating a sub-tank shown in FIG. **1**;

FIG. **3** is a plan view of the sub-tank shown in FIG. **2**;

FIG. **4**A is a sectional view taken along line A-A of FIG. **3**, FIG. **4**B is a sectional view taken along line B-B of FIG. **3**, FIG. **4**C is a sectional view taken along line C-C of FIG. **3**, and FIG. **4**D is a sectional view taken along line D-D of FIG. **3**.

FIG. **5** is a plan view illustrating an ink-jet head shown in FIG. **1**;

FIG. **6** is a partially enlarged view of FIG. **5**;

FIG. **7** is a sectional view taken along line VII-VII of FIG. **6**;

FIG. **8** is a sectional view taken along line VIII-VIII of FIG. **6**;

FIG. **9** is a sectional view illustrating a configuration of a differential pressure regulating valve shown in FIG. **1**;

FIGS. **10**A and **10**B are sectional views illustrating a configuration of a charge tank shown in FIG. **1**

FIGS. **11**A to **11**D are diagrams illustrating a first modified exemplary embodiment, which correspond to FIGS. **4**A to **4**D; and

FIGS. **12**A to **12**D are diagrams illustrating a second modified exemplary embodiment, which correspond to FIGS. **4**A to **4**D.

DETAILED DESCRIPTION

Hereinafter, exemplary embodiments of the present invention will be described.

FIG. **1** is a diagram schematically illustrating a configuration of a printer according to an exemplary embodiment of the invention. As shown in FIG. **1**, the printer **1** includes a carriage **2**, an ink-jet head **3**, a sub-tank **4**, ink cartridges **6***a* to **6***d*, tubes **5***a* to **5***d*, tubes **7***a* to **7***c*, a differential pressure regulating valve **9**, a charge tank **12**, an ink suction cap **13**, a suction pump **14**, and a switching unit **15**.

The carriage **2** is driven by a driving mechanism **18** and reciprocates in a scanning direction along two guide shafts **17** extending in parallel in the horizontal direction (scanning direction) of FIG. **1**. The ink-jet head **3** is mounted on the carriage **2** and ejects ink (liquid) from nozzles **95** (see FIG. **5**) formed on the bottom surface (nozzle surface) thereof onto a printing sheet P conveyed to the down side in FIG. **1** (in a sheet conveying direction) by a sheet conveying mechanism (not shown) while reciprocating in the scanning direction together with the carriage **2**. Accordingly, an image is printed onto the printing sheet P. It is noted that the nozzle surface is parallel to the horizontal direction and an ejecting direction of the ink from the nozzles **95** is perpendicular to the horizontal direction.

The sub-tank **4** is mounted on the carriage **2** and ink to be supplied to the ink-jet head **3** is temporarily contained in the sub-tank **4**. The ink cartridges **6***a* to **6***d* are connected to the tubes **5***a* to **5***d*. Ink of black, yellow, cyan, and magenta to be supplied to the ink-jet head **3** is contained in the ink cartridges **6***a* to **6***d*, respectively.

The tubes **5***a* to **5***d* have one end connected to the sub-tank **4** and the other end connected to the ink cartridges **6***a* to **6***d*. Four colors of ink contained in the ink cartridges **6***a* to **6***d* are supplied to the sub-tank **4** through the tubes **5***a* to **5***b*, respectively. Accordingly, four colors of ink are supplied from the sub-tank **4** to the inkjet head **3** and four colors of ink are ejected from the nozzles **95** (see FIG. **5**).

The tube **7***a* connects the sub-tank **4** and the charge tank **12**, the tube **7***b* connects the charge tank **12** and the differential pressure regulating valve **9**, and the tube **7***c* connects the differential pressure regulating valve **9** and the switching unit **15**. Accordingly, the sub-tank **4** and the switching unit **15** are connected through the tubes **7***a* to **7***c*, the charge tank **12**, and the differential pressure regulating valve **9**. A gas flow channel extending from a gas chamber **49** (described later) of the sub-tank **4** to the switching unit **15** through a discharge unit **23** (see FIG. **2**), the tube **7***a*, the charge tank **12**, the tube **7***b*, the differential pressure regulating valve **9**, and the tube **7***c* corresponds to a discharge channel.

As described later, the differential pressure regulating valve **9** switches the communication states (communicating state or communication blocked state) between the tube **7***a* and the tube **7***b*, thereby switching the communication states between the discharge channel and the suction pump **14**. As described later, when a portion of the discharge channel between the sub-tank **4** and the differential pressure regulating valve **9** is maintained in a negative pressure, the charge tank **12** serves to elongate the duration of the negative pressure.

The ink suction cap **13** is disposed to face the bottom surface of the ink-jet head **3** when the carriage **2** is located at the rightmost position of FIG. **1** in a movable range of the carriage **2**, and moves in a direction departing forward from the paper surface of FIG. **1** to cover the nozzles **95** formed in the bottom surface of the ink-jet head **3** when the ink-jet head **3** is located at the position facing the ink suction cap **13**. The ink suction cap **13** is connected to the switching unit **15**.

The suction pump **14** is connected to the switching unit **15**. The switching unit **15** selectively connects the suction pump **14** to one of the tube **7***c* and the ink suction cap **13**. By actuating the suction pump **14** in the state where the suction pump **14** is connected to the tube **7***c* by the switching unit **15**, it is possible to suction the gas in the discharge channel from the tube **7***c*. In addition, by actuating the suction pump **14** in the state where the suction pump **14** and the ink suction cap **13** are connected to each other by the switching unit **15**, it is possible to suction the thickened ink in the ink-jet head **3** from the nozzles **95** (see FIG. **5**).

The sub-tank **4** is described herein. FIG. **2** is a perspective view schematically illustrating the sub-tank **4** shown in FIG. **1**. FIG. **3** is a plan view of FIG. **2**. FIG. **4**A is a sectional view taken along line A-A of FIG. **3**. FIG. **4**B is a sectional view taken along line B-B of FIG. **3**. FIG. **4**C is a sectional view taken along line C-C of FIG. **3**. FIG. **4**D is a sectional view taken along line D-D of FIG. **3**. For the purpose of easily understanding the drawings, in FIG. **3**, inflow tubes **31***a* to **31***d* of a connection unit **21** (described later) and a discharge unit **23** (described later) are indicated by a two-dot chained line, and parts of a connecting portion **32** of the connection unit **21** and a sub-tank body **22** are not shown. As shown in FIGS. **2** to **4**D, the sub-tank **4** includes a connection unit **21**, a sub-tank body **22**, and a discharge unit **23**.

The connection unit **21** connects the tubes **5***a* to **5***d* to the sub-tank **4** and includes inflow tubes **31***a* to **31***d* and a connecting portion **32**. The inflow tubes **31***a* to **31***d* are cylindrical tubes extending in the sheet conveying direction in parallel to one another and are arranged in the scanning direction with a constant interval. The front ends of the inflow tubes **31***a* to **31***d* in FIG. **2** are connected to the tubes **5***a* to **5***d* (not shown in FIGS. **2** and **3**) and the back ends thereof in FIG. **2** are connected to the connecting portion **32**. The connecting portion **32** is bonded to the top surface of the sub-tank body **22** at one end in the scanning direction to allow the inflow tubes **31***a* to **31***d* to communicate with connection holes **41***a* to **41***d* of the sub-tank body **22** (described later).

The sub-tank body **22** includes connection holes **41***a* to **41***d*, ink flow channels **42***a* to **42***d*, **43***a* to **43***d*, **46***a* to **46***d*, and **47***a* to **47***d*, ink containing chambers **44***a* to **44***d*, damper films **45***a* to **45***d*, a gas chamber **49**, a gas permeable film **60**, and filters **70***a* to **70***d*. The connection holes **41***a* to **41***d* have a substantially circular shape in a plan view and are arranged in the vertical direction of FIG. **3** at the lower-right end of the sub-tank body **22** in FIG. **3**. The sub-tank body **22** is supplied with the ink from the connection holes **41***a* to **41***d*.

The ink flow channel **42***a* extends to the upside of FIG. **3** from the connection hole **41***a*, is bent to the upper-right side of FIG. **3** in the middle way, and extends to the position of the ink containing chambers **44***a* to **44***d* in the vicinity of the downside thereof in FIG. **3**.

The ink flow channel **42***b* extends to the left side of FIG. **3** from the connection hole **41***b*, is bent upward in the drawing in the middle way, is bent again to the upper-right side of FIG. **3** in the middle way, and extends to the position of the ink containing chambers **44***a* to **44***d* in the vicinity of the downside thereof in FIG. **3**.

The ink flow channel **42***c* extends to the left side of FIG. **3** from the connection hole **41***c*, is bent upward in the drawing in the middle way, is bent again to the upper-left side of FIG. **3** in the middle way, and extends to the position of the ink containing chambers **44***a* to **44***d* in the vicinity of the downside thereof in FIG. **3**.

The ink flow channel **42***d* extends to the left side of FIG. **3** from the connection hole **41***d*, is bent upward in the drawing in the middle way, is bent again to the upper-left side of FIG. **3** in the middle way, and extends to the position of the ink containing chambers **44***a* to **44***d* in the vicinity of the downside thereof in FIG. **3**.

By arranging the ink flow channels **42***a* to **42***d* as described above, the portions extending to the upside and the downside of FIG. **3** are arranged in the horizontal direction of FIG. **3** in the order of the ink flow channels **42***a*, **42***b*, **42***c*, and **42***d* from the right side.

The ink containing chambers **44***a* to **44***d* are arranged at positions of the ink flow channels **42***a* to **42***d* in the vicinity of the upper end thereof in FIG. **3** so as to overlap with each other in the plan view. The ink containing chambers **44***b*, **44***a*, **44***d*, and **44***c* are sequentially arranged in this order in the vertical direction as shown in FIGS. **4**A to **4**D. The ink containing chambers **44***a* to **44***d* have a substantially rectangular shape longitudinally extending in the horizontal direction of FIG. **3** in the plan view.

The upper surface of the ink containing chamber **44***b* and the lower surface of the ink containing chamber **44***a* are provided with the damper films **45***b* and **45***a*, respectively. The damper films **45***b* and **45***a* serve as walls defining the upper surface of the ink containing chamber **44***b* and the lower surface of the ink containing chamber **44***a*. A partition wall **50** is disposed between the ink containing chamber **44***b* and the ink containing chamber **44***a*, and the ink containing chamber **44***b* and the ink containing chamber **44***a* are partitioned by the partition wall **50**.

The upper surface of the ink containing chamber **44***d* and the lower surface of the ink containing chamber **44***c* are provided with the damper films **45***d* and **45***c*, respectively. The damper films **45***d* and **45***c* serve as walls defining the upper surface of the ink containing chamber **44***d* and the lower surface of the ink containing chamber **44***c*. A partition wall **51** is disposed between the ink containing chamber **44***d* and the ink containing chamber **44***c*, and the ink containing chamber **44***d* and the ink containing chamber **44***c* are partitioned by the partition wall **51**. A space is formed between the ink containing chamber **44***a* and the ink containing chamber **44***d* (between the damper film **45***a* and the damper film **45***d*).

Here, when the sub-tank **4** reciprocates in the scanning direction along with the carriage **2** at the time of performing a printing operation and the like, the ink in the sub-tank **4** vibrates to cause a variation in pressure of the sub-tank **4**. However, since the damper films **45***a* to **45***d* are deformed, the variation in pressure of the ink is suppressed.

The ink flow channel **43***a* extends from the front end (upper end in FIG. **3**) of the ink flow channel **42***a* to the same height as the ink containing chamber **44***a* (downside in FIG. **4**A), is bent to the left of FIG. **4**A at the position, and is then connected to the ink containing chamber **44***a*.

The ink flow channel **43***b* extends from the front end (upper end in FIG. **2**) of the ink flow channel **42***b* in the extending direction (to the left side of FIG. **4**B) of the ink flow channel **42***b* and is then connected to the ink containing chamber **44***b*. The ink flow channel **43***c* extends from the front end (upper end in FIG. **3**) of the ink flow channel **42***c* to the same height as the ink containing chamber **44***c* (downside in FIG. **4**C), is bent to the left of FIG. **4**C at the position, and is then connected to the ink containing chamber **44***c*.

The ink flow channel **43***d* extends from the front end (upper end in FIG. **3**) of the ink flow channel **42***d* to the same height as the ink containing chamber **44***d* (downside in FIG. **4**D), is bent to the left of FIG. **4**D at the position, and is then connected to the ink containing chamber **44***d*.

The ink flow channels **46***a* to **46***d* (second liquid flow channels) extend from the left ends of the ink containing chambers **44***a* to **44***d* in FIGS. **4**A to **4**D in the horizontal direction (to the left side in the drawings) and are connected to the ink flow channels **47***a* to **47***d*, respectively. The ink flow channels **47***a* to **47***d* (first liquid flow channels) extend in the vertical direction (in the direction perpendicular to the horizontal direction) and are arranged from the left of FIG. **3** in the horizontal direction of FIG. **3** in the order of the ink flow channels **47***a*, **47***b*, **47***c*, and **47***d*.

The lower ends of the ink flow channels **47***a* to **47***d* are ink supply ports **48***a* to **48***d* of which the lower ends are opened, and the ink supply ports **48***a* to **48***d* are connected to the ink supply holes **89** (see FIG. **5**) formed in the top surface of the ink-jet head **3**. That is, the ink-jet head **3** is connected to the downstream end of the ink flow channels **47***a* to **47***d*. The ink in the ink flow channels **47***a* to **47***d* are supplied from the ink supply ports **48***a* to **48***d* to the ink-jet head **3**.

The gas chamber **49** is formed at a position overlapping the ink flow channels **47***a* to **47***d* as viewed in the horizontal direction in FIGS. **4**A to **4**D so as to cover the ink flow channels **47***a* to **47***d*. The gas permeable film **60** is disposed between the ink flow channels **47***a* to **47***d* and the gas chamber **49** so as to cover the ink flow channels **47***a* to **47***d*, and extends in the vertical direction. The gas permeable film **60** forms left side walls (a part of walls along the extending direction) of the ink flow channels **47***a* to **47***d* in FIGS. **4**A to **4**D and serves as a wall partitioning the ink flow channels **47***a* to **47***d* and the gas chamber **49**.

The gas permeable film **60** passes only gas and does not pass ink or liquid other than gas. Accordingly, when the gas in the discharge channel is suctioned by the suction pump **14** or when the pressure of the discharge channel is maintained in a negative pressure lower than the atmospheric pressure as described later, only the gas in the ink flow channels **47***a* to **47***d* is suctioned due to the negative pressure of the discharge channel and is discharged to the gas chamber **49** (discharge channel).

The filters **70***a* to **70***d* serve to remove particles in the ink in the ink flow channels **47***a* to **47***d* and are disposed at positions overlapping the gas permeable film **60** in the horizontal direction in the vicinity of the ink supply ports **48***a* to **48***d* of the ink flow channels **47***a* to **47***d*, respectively. The filters **70***a* to **70***d* are tilted about the horizontal direction so that a left portion (portion closer to the gas permeable film **60**) in FIGS. **4**A to **4**D is located higher, and the left end in FIGS. **4**A to **4**D is connected to the gas permeable film **60**.

In the ink flow channels **47***a* to **47***d*, bubbles can be easily attached to the surfaces of the filters **70***a* to **70***d*. When the bubbles attached to the filters **70***a* to **70***d* stay, the bubbles may flow into the ink-jet head **3** along with the ink, thereby causing a variation in ink ejection characteristic of the nozzles **95** (see FIG. **5**). However, in this exemplary embodiment, since the filters **70***a* to **70***d* are located at the positions overlapping with the gas permeable film **60** in the horizontal direction and the left end in FIGS. **4**A to **4**D is connected to the gas permeable film **60**, the bubbles attached to the filters **70***a* to **70***d* are discharged to the gas chamber **49** through the gas permeable film **60**.

The bubbles can easily stay particularly on the lower surfaces of the filters **70***a* to **70***d*. However, since the filters **70***a* to **70***d* are tilted about the horizontal direction so that the portion closer to the left in FIGS. **4**A to **4**D is located higher, the gas attached to the lower surfaces of the filters **70***a* to **70***d* move to the vicinity of the gas permeable film **60** to the upper-left side in FIGS. **4**A to **4**D along the lower surfaces of the filters **70***a* to **70***d*. Accordingly, it is possible to efficiently discharge the gas attached to the lower surfaces of the filters **70**a to **70**d to the gas chamber **49**.

In the printer **1**, the ink in the ink cartridges **6**a to **6**d flows into the inflow tubes **31**a to **31**d from the tubes **5**a to **5**d and flows into the ink containing chambers **44**a to **44**d through the connection holes **41**a to **41**d and the ink flow channels **42**a to **42**d and **43**a to **43**d, respectively. The ink temporarily contained in the ink containing chambers **44**a to **44**d flows into the ink flow channels **47**a to **47**d from the ink flow channels **46**a to **46**d and is then supplied to the inkjet head **3** through the ink supply ports **48**a to **48**d after the particles are removed therefrom by the filters **70**a to **70**d, respectively.

The flow channels extending from the ink cartridges **6**a to **6**d to the ink-jet head **3** through the tubes **5**a to **5**d, the inflow tubes **31**a to **31**d, the connection holes **41**a to **41**d, the ink flow channels **42**a to **42**d and **43**a to **43**d, the ink containing chambers **44**a to **44**d, and the ink flow channels **46**a to **46**d and **47**a to **47**d correspond to the liquid supply channels.

Here, the ink flow channels **47**a to **47**d and the gas permeable film **60** extend in the vertical direction (the direction intersecting the horizontal direction). Accordingly, when the gas flows into the ink flow channels **47**a to **47**d, the liquid level of the ink in the ink channels **47**a to **47**d is lowered more as the amount of gas flowing therein becomes more, for example, as indicated by a dot dashed line in FIGS. **4**A to **4**D. As the liquid level of the ink is lowered, the contact area between the gas in the ink flow channels **47**a to **47**d and the gas permeable film **60** increases. Accordingly, even when a large amount of gas flows into the sub-tank **4** from the ink cartridges **6**a to **6**d, it is possible to efficiently discharge the gas from the ink flow channels **47**a to **47**d to the gas chamber **49** through the gas permeable film **60**.

Here, since the ink flow channels **47**a to **47**d extend in the vertical direction and are connected to the inkjet head **3** at the ink supply ports **48**a to **48**d disposed at the lower end portions of the ink flow channels **47**a to **47**d, the ink flows vertically in the ink flow channels **47**a to **47**d toward the ink-jet head **3**. Accordingly, when the gas flows into the flow channels **47**a to **47**d, the liquid level of the ink in the ink flow channels **47**a to **47**d is surely lowered. By setting the extending direction of the ink flow channels **47**a to **47**d to the vertical direction, it is possible to minimize the sizes of the ink flow channels **47**a to **47**d in the horizontal direction.

When the ink in the ink flow channels **47**a to **47**d is thickened, the thickened ink may be attached to the gas permeable film **60** and the gas permeable film **60** may be clogged by the thickened ink. However, since the ink flow channels **46**a to **46**d connected to the upstream ends of the ink flow channels **47**a to **47**d extend in the horizontal direction and the connecting portions to the ink flow channels **47**a to **47**d are located at the positions overlapping with the gas permeable film **60** in the horizontal direction, the ink flowing in the ink flow channels **47**a to **47**d from the ink flow channels **46**a to **46**d flows toward the gas permeable film **60** in the horizontal direction. Accordingly, the ink thickened and attached to the gas permeable film **60** is removed by the flow of ink flowing from the ink flow channels **46**a to **46**d into the ink flow channels **47**a to **47**d.

The discharge unit **23** forms a discharge channel discharging the gas in the sub-tank body **22** to the outside, and includes a connecting portion **61** and a discharge tube **62**. The connecting portion **61** is disposed at positions overlapping with the ink flow channels **47**a to **47**d and the gas chamber **49** as viewed from the top side of the sub-tank body **22** so as to cover the ink flow channels **47**a to **47**d and the gas chamber **49** above the ink flow channels **47**a to **47**d and the gas chamber **49**. A communication channel **63** and a gas chamber **65** forming the discharge channel are included in the connecting portion **61**.

The gas chamber **65** is disposed at a position overlapping with the ink flow channels **47**a to **47**d and the gas chamber **49** in the plan view so as to cover the ink flow channels **47**a to **47**d and the gas chamber **49**. The communication channel **63** extends in the vertical direction between the gas chamber **49** and the gas chamber **65** and allows the gas chamber **49** to communicate with the gas chamber **65**.

The discharge tube **62** is a cylindrical tube, one end of which is connected to substantially center portion of the lower side surface of the gas chamber **65** in FIG. **3**, extends to the downside of FIG. **3**, is bent to the left side of FIG. **3** in the middle way. The inflow tubes **31**a to **31**d and the discharge tube **62** are arranged in the scanning direction with a constant interval. The end of the discharge tube **62** extending to the left side of FIG. **3** is connected to the tube **7**a (not shown in FIGS. **2** and **3**).

The ink-jet head **3** will be described now. FIG. **5** is a plan view of the ink-jet head **3** shown in FIG. **1**. FIG. **6** is a partially enlarged view of FIG. **5**. FIG. **7** is a sectional view taken along line VII-VII of FIG. **6**. FIG. **8** is a sectional view taken along line VIII-VIII of FIG. **6**. Here, for the purpose of easily understanding the drawings, in FIG. **5**, a pressure chamber **90** and through holes **92** to **94** (described later) are not shown and the nozzles **95** are more enlarged than those of FIGS. **6** to **8**.

As shown in FIGS. **5** to **8**, the ink-jet head **3** includes a flow channel unit **67** having an ink flow channel such as the pressure chamber **90** formed therein and a piezoelectric actuator **68** disposed on the top surface of the flow channel unit **67**.

The flow channel unit **67** is formed by stacking four plates of a cavity plate **71**, a base plate **72**, a manifold plate **73**, and a nozzle plate **74** sequentially from the top side. Among the four plates **71** to **74**, three plates **71** to **73** other than the nozzle plate **74** are made of a metal material such as stainless and the nozzle plate **74** is made of a synthetic resin material such as polyimide. Alternatively, the nozzle plate **74** may be made of the metal material, similarly to the three plates **71** to **73**.

Plural nozzles **95** are formed in the nozzle plate **74**. The plural nozzles **95** are arranged in the sheet conveying direction (vertical direction in FIG. **5**) to form nozzle rows **88**. Four nozzle rows **88** are arranged in the scanning direction (horizontal direction in FIG. **5**). The four nozzle rows **88** including the nozzles **95** for ejecting black, yellow, cyan, and magenta are arranged sequentially from the left nozzle row **88** in FIG. **5**.

Plural pressure chambers **90** are formed in the cavity plate **71** to correspond to the plural nozzles **95**. The pressure chambers **90** have a substantially elliptical planar shape having the scanning direction as its longitudinal direction and the right end of each pressure chamber **90** overlaps with the corresponding nozzle **95** in the plan view. The base plate **72** has through holes **92** and **93** formed at positions overlapping with both ends in the longitudinal direction of the pressure chamber **90** in the plan view.

Four manifold flow channels **91** extending in the sheet conveying direction are formed on the left side of the nozzle rows **88** in the manifold plate **73** to correspond to the four nozzle rows **88**. Each manifold flow channel **91** overlaps with substantially the left half of the corresponding pressure chamber **90** in the plan view. The manifold flow channels **91** include ink supply holes **89**, respectively in the upper ends of FIG. **5**. The ink supply holes **89** are connected to the ink supply ports **48**a to **48**d of the sub-tank **4** as described above, and the ink in the sub-tank **4** is supplied to the manifold flow channels **91** through the ink supply holes **89**. The manifold plate **73** has through holes **94** formed at positions overlapping with the through holes **93** and the nozzles **95** in the plan view.

In the flow channel unit **67**, the manifold flow channel **91** communicates with the pressure chamber **90** through the through hole **92** and the pressure chamber **90** communicates with the nozzle **95** through the through holes **93** and **94**. In this way, plural individual ink flow channels extending from the exits of the manifold flow channels **91** to the nozzles **95** through the pressure chambers **90** are formed in the flow channel unit **67**.

The piezoelectric actuator **68** includes a vibrating plate **81**, a piezoelectric layer **82**, and plural individual electrodes **83**. The vibrating plate **81** is made of a conductive material such as a metal material and is bonded to the top surface of the cavity plate **71** to cover the plural pressure chambers **90**. The vibrating plate **81** having conductivity serves as a common electrode for applying an electric field to a portion of the piezoelectric layer **82** between the individual electrodes **83** as described later, is connected to a driver IC (not shown), and is always maintained in a ground potential.

The piezoelectric layer **82** has mixed crystals of lead titanate and lead zirconate, is made of a piezoelectric material containing lead zirconate titanate as a main component and having a ferroelectric property, and is disposed continuously on the top surface of the vibrating plate **81** to cover the plural pressure chambers **90**. The piezoelectric layer **82** is polarized in advance in its thickness direction.

The plural individual electrodes **83** are disposed on the top surface of the piezoelectric layer **82** to correspond to the plural pressure chambers **90**. The individual electrodes **83** have a substantially elliptical planar shape slightly smaller than the pressure chambers **90** and are disposed at positions overlapping with the center portions of the pressure chambers **90** in the plan view. An end (left end in FIG. **6**) in the longitudinal direction of each individual electrode **83** extends to the left side up to the position not overlapping with the pressure chamber **90** in the plan view and the end portion serves as a contact point **83***a*. The contact point **83***a* is connected to the driver IC (not shown) through a wiring member such as a flexible printed circuit board (FPC, not shown). A driving voltage is selectively applied to the individual electrodes **83** by the driver IC.

Here, a method of driving the piezoelectric actuator **68** will be described. In the piezoelectric actuator **68**, the potentials of the individual electrodes **83** are maintained in a ground potential in advance by the driver IC (not shown). When the driving voltage is applied to one of the plural individual electrodes **83** by the driver IC, a potential difference is generated between the individual electrode **83** to which the driving voltage is applied and the vibrating plate **81** as the common electrode maintained in the ground potential and thus an electric field in the thickness direction is generated in the portion of the piezoelectric layer **82** interposed between the individual electrode **83** and the vibrating plate **81**. Since the direction of the electric field is parallel to the polarization direction of the piezoelectric layer **82**, the portion of the piezoelectric layer **82** contracts in the horizontal direction perpendicular to the polarization direction. Accordingly, portions of the vibrating plate **81** and the piezoelectric layer **82** opposed to the pressure chamber **90** corresponding to the individual electrode **83** to which the driving voltage is applied are deformed to be convex toward the pressure chamber **90** as a whole and the volume of the pressure chamber **90** decreases. Accordingly, the pressure of the ink in the pressure chamber **90** increases and the ink is ejected from the nozzle **95** communicating with the pressure chamber **90**.

The differential pressure regulating valve **9** will be described now. FIG. **9** is a sectional view illustrating a configuration of the differential pressure regulating valve **9** shown in FIG. **1**.

As shown in FIG. **9**, the differential pressure regulating valve **9** includes gas chambers **101** and **102** and a communication channel **103** forming the discharge channel and a valve body **104**. The gas chamber **101** and the gas chamber **102** are arranged in the horizontal direction of FIG. **9**. The gas chamber **101** communicates with the tube **7***c* at a communication hole **107** disposed at the right end in FIG. **9** and the gas chamber **102** communicates with the tube **7***b* at a communication hole **109** disposed at the left end in FIG. **9**. The communication channel **103** is a flow channel having a substantially circular shape as viewed in the horizontal direction of FIG. **9**, extending in the horizontal direction between the gas chamber **101** and the gas chamber **102**, and allowing the gas chamber **101** and the gas chamber **102** to communicate with each other and the diameter thereof is smaller than the length of the gas chambers **101** and **102** in the vertical direction and the direction perpendicular to the paper surface of FIG. **9**.

The valve body **104** includes a cylindrical portion **104***a*, a blocking portion **104***b*, and a drop-preventing portion **104***c*. The cylindrical portion **104***a* has a substantially cylindrical shape having a diameter slightly smaller than that of the communication channel **103** and extends from the left end of the gas chamber **101** in FIG. **9** to the right end of the gas chamber **102** in FIG. **9** through the communication channel **103**. The blocking portion **104***b* is disposed at the right end of the cylindrical portion **104***a* in FIG. **9** and extends from the cylindrical portion **104***a* to the outside in the diameter direction of the cylindrical portion **104***a* in a mountain shape, and its diameter is greater than the communication channel **103**. The drop-preventing portion **104***c* is disposed at the left end of the cylindrical portion **104***a* in FIG. **9** and extends from the cylindrical portion **104***a* to the outside in the diameter direction of the cylindrical portion **104***a*, and its diameter is greater than that of the communication channel **103**. Plural through holes **104***d* are formed in the drop-preventing portion **104***c* at positions overlapping with the edge of the communication channel **103** in the horizontal direction in FIG. **9**.

When the gas in the discharge channel is suctioned by the suction pump **14**, the valve body **104** moves to the right in FIG. **9** due to the suction force of the suction pump **14**. Accordingly, a gap is generated between the blocking portion **104***b* and the left wall of the gas chamber **101** in FIG. **9** (the valve is opened). As a result, the gas chamber **101** and the gas chamber **102** communicate with each other through the through hole **104***d* and the communication channel **103**. Accordingly, the discharge channel communicates with the switching unit **15** (suction pump **14**). At this time, since the right surface of the drop-preventing portion **104***c* comes in contact with the right wall of the gas chamber **102**, the valve body **104** is prevented from dropping from the communication channel **103**. By suctioning the gas in the discharge channel by the use of the suction pump **14**, the pressure of the discharge channel decreases into a negative pressure lower than the atmospheric pressure.

On the other hand, the pressure of the gas chamber **102** is a negative pressure. Accordingly, after the gas in the discharge channel is suctioned by the suction pump **14**, the valve body **104** is suctioned due to the negative pressure to move to the left in FIG. **8** and the outer edge of the blocking portion **104***b* is pressed against the left wall of the gas chamber **101** in FIG. **9**. As a result, the gap between the blocking portion **104***b* and the left wall of the gas chamber **101** disappears and the communication between the gas chamber **101** and the gas chamber **102** through the communication channel **103** is blocked. At this time, the portion of the discharge channel between the differential pressure regulating valve **9** and the gas permeable film **60** does not communicate with the outside and is thus closed.

Accordingly, the portion of the discharge channel between the differential pressure regulating valve **9** and the gas permeable film **60** is maintained in the negative pressure. As a result, even after the gas in the discharge channel is suctioned by the suction pump **14**, the gas in the ink flow channels **47***a* to **47***d* is suctioned due to the negative pressure and is discharge to the discharge channel.

In this way, when the pressure of the space in the discharge channel closer to the sub-tank **4** than the valve body **104** is sufficiently smaller than the pressure of the space in the discharge channel closer to the switching unit **15** (the suction pump **14**) than the valve body **104** (when the pressure of the space in the discharge channel close to the sub-tank **4** is smaller and the difference in pressure between the two spaces is greater than a predetermined value), the differential pressure regulating valve **9** according to this exemplary embodiment blocks the communication between the two spaces. Otherwise (when the difference in pressure between the two spaces is smaller than the predetermined value or when the pressures of the two spaces are equal to each other or the pressure of the space in the discharge channel close to the switching unit **15** is smaller, the differential pressure regulating valve permits the communication between the two spaces. The differential pressure regulating valve **9** according to this exemplary embodiment is also a one-way valve permitting a flow of gas from the sub-tank **4** to the switching unit **15** and blocking a flow of gas from the switching unit **15** to the sub-tank **4**.

The charge tank **12** is described now. FIGS. **10**A to **10**B is a sectional view illustrating a configuration of the charge tank **12**. Specifically, FIG. **10**A shows a state where the pressure of a charge chamber **122***c* (described later) is the atmospheric pressure and FIG. **10**B shows a state where the pressure of the charge chamber **122***c* is a negative pressure. As shown in FIGS. **10**A and **10**B, the charge tank **12** includes a gas flow channel **121** forming the discharge channel, a bellows portion **122**, and a volume detecting sensor **123**.

The gas flow channel **121** extends in the horizontal direction in FIGS. **10**A and **10**B and communicates with the tubes **7***a* and **7***b* at communication holes **121***a* and **121***b* disposed on both ends. A communication hole **121***c* allowing the gas flow channel **121** to communicate with a below-described charge chamber **122***c* of the bellows portion **122** is disposed in the top surface of the substantially center portion of the gas flow channel **121** in FIGS. **10**A and **10**B.

The bellows portion **122** extends in the vertical direction in FIGS. **10**A and **10**B and has a charge chamber **122***c* (volume varying chamber) surrounded with a top wall **122***b* and a side wall **122***a*. The top wall **122***b* is a wall defining the upper end of the charge chamber **122***c* and has a substantially circular planar shape. The side wall **122***a* is a wall defining the side surface of the charge chamber **122***c* and extends downward from the outer edges of the top wall **122***b* while being alternately bent in the opposite directions. Accordingly, by applying a vertical force to the top wall **122***b*, the top wall **122***b* moves in the vertical direction and the bending angle θ of the side wall **122***a* varies, whereby the volume of the charge chamber **122***c* varies. The lower end of the charge chamber **122***c* is opened and is connected to the communication hole **121***c*. Accordingly, the gas flow channel **121** communicates with the charge chamber **122***c*.

When the pressure of the charge chamber **122***c* is the atmospheric pressure, as shown in FIG. **10**A, the top wall **122***b* of the bellows portion **122** is located at the highest position and the bending angle θ of the side wall **122***a* is the largest. When the pressure of the charge chamber **122***c* decreases by suctioning the gas from the tube **7***c* by actuating the suction pump **14**, a downward force acts on the top wall **122***b* due to the difference between the external atmospheric pressure and the negative pressure of the charge chamber **122***c*. Accordingly, as shown in FIG. **10**B, the top wall **122***b* moves down and the bending angle θ of the side wall **122***a* decreases with the movement. With the deformation of the bellows portion **122**, the volume of the charge chamber **122***c* decreases.

Here, when the bending angle θ of the side wall **122***a* decreases, an upward restoring force for restoring the top wall to the state shown in FIG. **10**A acts on the side wall **122***a* and the restoring force increases as the bending angle θ of the side wall **122***a* decreases. Accordingly, in the bellows portion **122**, the variation in volume of the charge chamber **122***c* is stopped when the force resulting from the difference between the atmospheric pressure and the pressure of the charge chamber **122***c* is balanced with the restoring force. As a result, as the pressure of the charge chamber **122***c* becomes lower, the volume of the charge chamber **122***c* becomes smaller. That is, the pressure of the charge chamber **122***c* and the volume of the charge chamber **122***c* have a predetermined relation.

On the contrary, as shown in FIG. **10**B, when the charge chamber **122***c* is maintained in the negative pressure and the gas in the ink flow channels **47***a* to **47***d* is discharged to the gas chamber **49** through the gas permeable film **60**, the pressure of the charge chamber **122***c* communicating with the gas chamber **49** increases as much as the discharged gas. Accordingly, the downward force generated due to the difference between the atmospheric pressure and the pressure of the charge chamber **122***c* decreases, the top wall **122***b* of the bellows portion **122** moves up, and the bending angle θ of the side wall **122***a* increases with the movement. With the deformation of the bellows portion **122**, the volume of the charge chamber **122***c* increases.

Here, since the charge chamber **122***c* communicates with the discharge channel, the total volume of the discharge channel and the charge chamber **122***c* increases as much as the volume of the charge chamber **122***c*, compared with the volume of the discharge channel not having the charge tank **12**. Accordingly, the increase in pressure of the discharge channel can be slowed when the gas flows into the discharge channel from the ink flow channels **47***a* to **47***d*, thereby elongating the time when the discharge channel is maintained in the negative pressure. Even when the gas flows into the discharge channel from the ink flow channels **47***a* to **47***d* and the volume of the charge chamber **122***c* increases, the variation in volume of the charge chamber **122***c* is stopped by means of the balance between the force resulting from the difference between the atmospheric pressure and the pressure of the charge chamber **122***c* and the restoring force due to the side wall **122***a* of the bellows portion **122**, similarly to the case where the gas in the discharge channel is suctioned by the suction pump **14**. That is, in this case, the pressure of the charge chamber **122***c* and the volume of the charge chamber **122***c* have a predetermined relation.

The volume detecting sensor **123** includes a movable portion **124**, plural slits **125**, and a slit detecting sensor **126**. The movable portion **124** moves up and down along with the top wall **122***b* of the bellows portion **122**. The plural slits **125** are disposed at the right end of the movable portion **124** in FIGS. **10**A and **10**B, extend in the horizontal direction in the drawing, and are arranged in the vertical direction. The slit detecting sensor **126** detects that the slits **125** vertically pass through the slit detecting sensor **126**. Since the plural slits **125** move up and down along with the top wall **122***b*, it is possible to detect the volume of the charge chamber **122***c* by detecting that the slits **125** pass through the slit detecting sensor **126** by the use of the slit detecting sensor **126**.

As described above, the position of the top wall **122***b*, that is, the volume of the charge chamber **122***c*, and the pressure of the charge chamber **122***c* have a predetermined relation. Accordingly, the volume detecting sensor **123** can detect the pressure of the charge chamber **122***c* by detecting that the plural slits **125** disposed in the movable portion **124** moving up and down along with the top wall **122***b* pass through the slit detecting sensor **126** by the use of the slit detecting sensor **126**.

According to the above-described exemplary embodiment, the ink flow channels **47***a* to **47***d* extend in the vertical direction (in the direction intersecting the horizontal direction) and the gas permeable film **60** forms a part of the side walls (the walls along the extending direction) of the ink flow channels **47***a* to **47***d*. Accordingly, as the amount of gas flowing into the ink flow channels **47***a* to **47***d* becomes increase, the liquid level in the liquid flow channels **47***a* to **47***d* is lowered and the contact area between the gas in the ink flow channels **47***a* to **47***d* and the gas permeable film **60** becomes large. Accordingly, even when a large amount of gas flows into the ink flow channels **47***a* to **47***d*, it is possible to efficiently discharge the gas in the ink flow channels **47***a* to **47***d*.

Here, since the ink flow channels **47***a* to **47***d* extend in the vertical direction and are connected to the ink-jet head **3** at the ink supply ports **48***a* to **48***d* at the lower end thereof, the ink flows through the ink flow channels **47***a* to **47***d* in the vertical direction to the ink-jet head **3**. Accordingly, when the gas flows into the ink flow channels **47***a* to **47***d*, the liquid level of the ink in the ink flow channels **47***a* to **47***d* is surely lowered.

Since the ink flow channels **47***a* to **47***d* extend in the vertical direction, it is possible to minimize the sizes of the ink flow channels **47***a* to **47***d* in the horizontal direction.

In the ink flow channels **47***a* to **47***d*, the ink may be thickened and attached to the gas permeable film **60** and the gas permeable film **60** may be clogged by the attached ink. However, since the ink flow channels **46***a* to **46***d* connected to the upstream ends of the ink flow channels **47***a* to **47***d* extend in the horizontal direction and the ink flow channels **46***a* to **46***d* are connected to the ink flow channels **47***a* to **47***d* at the positions overlapping with the gas permeable film **60** in the horizontal direction (the horizontal direction in FIGS. **4**A to **4**D), the ink flowing into the ink flow channels **47***a* to **47***d* from the ink flow channels **46***a* to **46***d* flows to the gas permeable film **60**. Accordingly, it is possible to remove the thickened ink attached to the gas permeable film **60** by the use of the flow of ink.

Bubbles can be easily attached to the surfaces of the filters **70***a* to **70***d*. However, since the filters **70***a* to **70***d* are disposed at the positions overlapping with the gas permeable film **60** in the horizontal direction, the bubbles attached to the filters **70***a* to **70***d* are discharged from the gas permeable film **60** to the gas chamber **49**. Bubbles can be easily accumulated particularly on the lower surfaces of the filters **70***a* and **70***d*. However, since the filters **70***a* to **70***d* are tilted with respect to the horizontal direction so that the portion closer to the gas permeable film **60** is located higher, the bubbles attached to the lower surfaces of the filters **70***a* to **70***d* move to the end of the gas permeable film **60** along the lower surfaces of the filters **70***a* to **70***d*. Accordingly, it is possible to efficiently discharge the bubbles attached to the filters **70***a* to **70***d*.

While the present invention has been shown and described with reference to certain exemplary embodiments thereof, it will be understood by those skilled in the art that various changes in form and details may be made therein without departing from the spirit and scope of the invention as defined by the appended claims.

Various modified exemplary embodiments will be described. Here, elements similar to above-described exemplary embodiment are denoted by the same reference numerals and description thereof is properly omitted.

In a first modified exemplary embodiment, as shown in FIGS. **11**A to **11**D, filters **170***a* to **170***d* extend in the horizontal direction and are connected to the gas permeable film **60** at the left end portions in FIGS. **11**A to **11**D. In this case, since the gas attached to the filters **170***a* to **170***d* is discharged from the gas permeable film **60** to the gas chamber **49**, it is possible to efficiently discharge the gas attached to the filters **170***a* to **170***d*.

In a second modified exemplary embodiment, as shown in FIGS. **12**A to **12**D, a gas permeable film **160** extends in a direction tilted with respect to the vertical direction and an intersection angle of the gas permeable film **160** with respect to the horizontal direction (the horizontal direction in FIGS. **12**A to **12**D) is ϕ. In this case, as the amount of gas flowing into the ink flow channels **47***a* to **47***d* becomes greater, the liquid level of the ink flow channels **47***a* to **47***d* is lowered and the contact area between the gas in the ink flow channels **47***a* to **47***d* and the gas permeable film **160** becomes greater. Accordingly, even when a large amount of gas flows into the ink flow channels **47***a* to **47***d*, it is possible to efficiently discharge the gas. As the extending direction of the gas permeable film **160** gets closer to the horizontal direction, the size of the ink flow channels **47***a* to **47***d* in the horizontal direction (the horizontal direction in FIGS. **12**A to **12**D) becomes greater. Accordingly, in view of preventing such increase in the size of ink flow channels **47***a* to **47***d* in the horizontal direction, it is preferable that the intersection angle (p of the gas permeable film **160** with respect to the horizontal direction is in the range of 45° to 135° (when (ϕ=90°, the configuration of the above-described exemplary embodiment is obtained).

Although the ink flow channels **47***a* to **47***d* extend in the vertical direction in the above-described exemplary embodiment, the inventive concept of the present invention is not limited to the configuration. The ink flow channels **47***a* to **47***d* may extend in the direction intersecting the horizontal direction other than the vertical direction. In this case, as the amount of gas flowing into the ink flow channels **47***a* to **47***d* becomes greater, the liquid level of the ink in the ink flow channels **47***a* to **47***d* is lowered and the contact area between the gas in the ink flow channels **47***a* to **47***d* and the gas permeable film **60** becomes greater. In this case, in order to prevent the ink flow channels **47***a* to **47***d* from excessively increasing in size in the horizontal direction, it is preferable that the intersection angle of the ink flow channels **47***a* to **47***d* about the horizontal direction is in the range of 45° to 135°, similarly to the gas permeable film as described above.

In the above-described exemplary embodiment, the filters **70***a* to **70***d* are disposed in the ink flow channels **47***a* to **47***d*. However, the filters may be disposed at positions other than the ink flow channels **47***a* to **47***d*.

In the above-described exemplary embodiment, the ink flow channels **46***a* to **46***d* connected to the upstream ends of the ink flow channels **47***a* to **47***d* extend in the horizontal direction and are connected to the ink flow channels **47***a* to **47***d* at the positions opposed to the gas permeable film **60** in the horizontal direction. However, the extending direction of the ink flow channels **46**_a_ to **46**_d_ and the connecting positions to the ink flow channels **47**_a_ to **47**_d_ are not limited to the above-described configuration.

In the above-described exemplary embodiment, it is described that the gas permeable film **60** forms the walls of the ink flow channels **47**_a_ to **47**_d_ formed in the sub-tank **4** in the extending direction thereof. However, the inventive concept of the present invention is not limited to this configuration. The gas permeable film may form a wall surface in the extending direction of the portions (first liquid flow channel) extending in a direction intersecting the horizontal direction other than the ink flow channels **47**_a_ to **47**_d_, in the ink flow channels extending from the ink cartridges **6**_a_ to **6**_d_ to the ink-jet head **3**.

Although it has been described above that the invention is applied to a printer ejecting ink from the nozzles, the invention may be applied to liquid ejecting devices ejecting liquids other than ink from nozzles.

What is claimed is:

1. A liquid ejecting device comprising:

a liquid ejecting head including a nozzle for ejecting a liquid, wherein the liquid is ejected from the nozzle in an ejecting direction;

a liquid supply channel connected to the liquid ejecting head to supply the liquid to the liquid ejecting head;

a discharge channel connected to the liquid supply channel through a connecting portion to discharge a gas in the liquid supply channel;

a gas permeable film disposed in the connecting portion between the liquid supply channel and the discharge channel, the gas permeable film configured to pass the gas and do not pass the liquid, the gas permeable film partitioning the liquid supply channel and the discharge channel; and

a suction unit connected to the discharge channel so as to suction the gas in the discharge channel,

wherein the liquid supply channel includes a first liquid flow channel extending in an extending direction intersecting a horizontal direction perpendicular to the ejecting direction, and

wherein the gas permeable film defines a part of the first liquid flow channel, the part of the first liquid flow channel extending in the extending direction.

2. The liquid ejecting device according to claim **1**,

wherein the liquid supply channel further includes a second liquid flow channel connected to an upstream portion of the first liquid flow channel through a connecting portion,

wherein the second liquid flow channel extends in the horizontal direction, and

wherein the connecting portion between the first liquid flow channel and the second liquid flow channel is located at a position overlapping with the gas permeable film in the horizontal direction.

3. The liquid ejecting device according to claim **1**,

wherein an intersection angle of the gas permeable film with respect to the horizontal direction is in the range of 45° to 135°.

4. The liquid ejecting device according to claim **1**,

wherein the first liquid flow channel extends in a vertical direction perpendicular to the horizontal direction, and

wherein a downstream end of the first liquid flow channel is connected to the liquid ejecting head.

5. The liquid ejecting device according to claim **1**, further comprising a filter for removing particles from the liquid flowing in the first liquid flow channel,

wherein the filter is provided at a position overlapping with the gas permeable film in the horizontal direction.

6. The liquid ejecting device according to claim **5**,

wherein the filter is tilted with respect to the horizontal direction so that a portion of the filter closer to the gas permeable film is located higher.

7. The liquid ejecting device according to claim **1**,

wherein the liquid ejecting head includes a nozzle surface provided with the nozzle, and

wherein the horizontal direction is parallel to the nozzle surface.

8. The liquid ejecting device according to claim **5**,

wherein the filter is connected to the gas permeable film.

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